VOL. XXXVI. No. 12. DECEMBER, 1958

THE STRUCTURAL ENGINEER

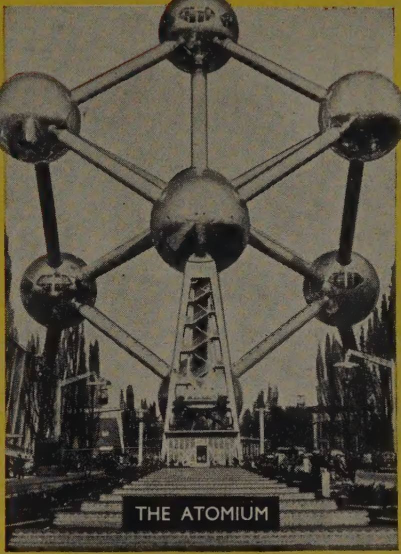
THE JOURNAL OF THE
INSTITUTION OF STRUCTURAL ENGINEERS

Presidential Address: The Structural Engineer at Large
by Gordon S. McDonald

The Design and Construction of Pelham Bridge, Lincoln
by S. M. Reisser (Member), K. M. Wright and D. Bolton

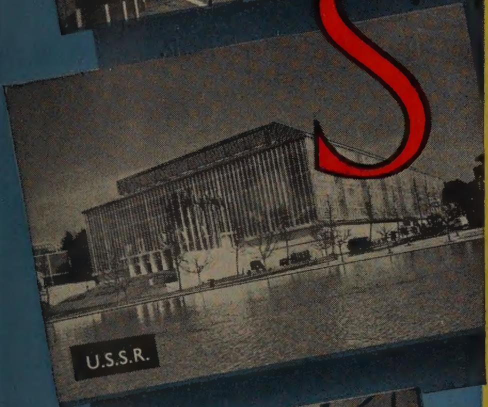
Arching Action in Reinforced Concrete Slabs
Written Discussion on the Paper by Professor A. J. Ockleston (Member)

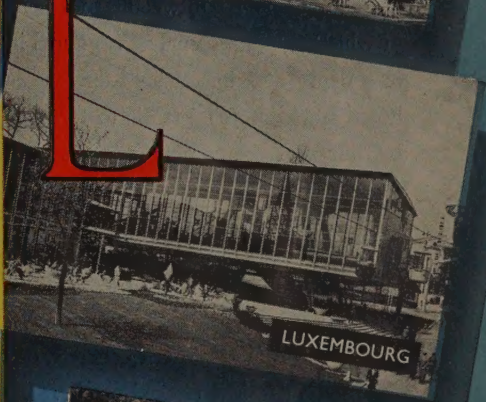
FOUR SHILLINGS AND SIXPENCE

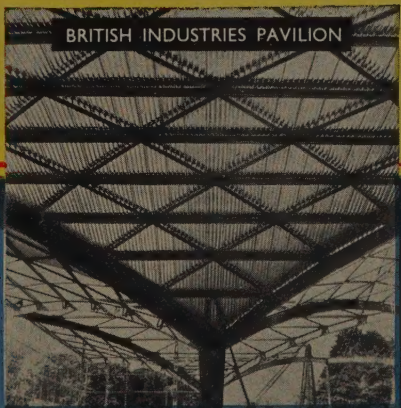


STEEL

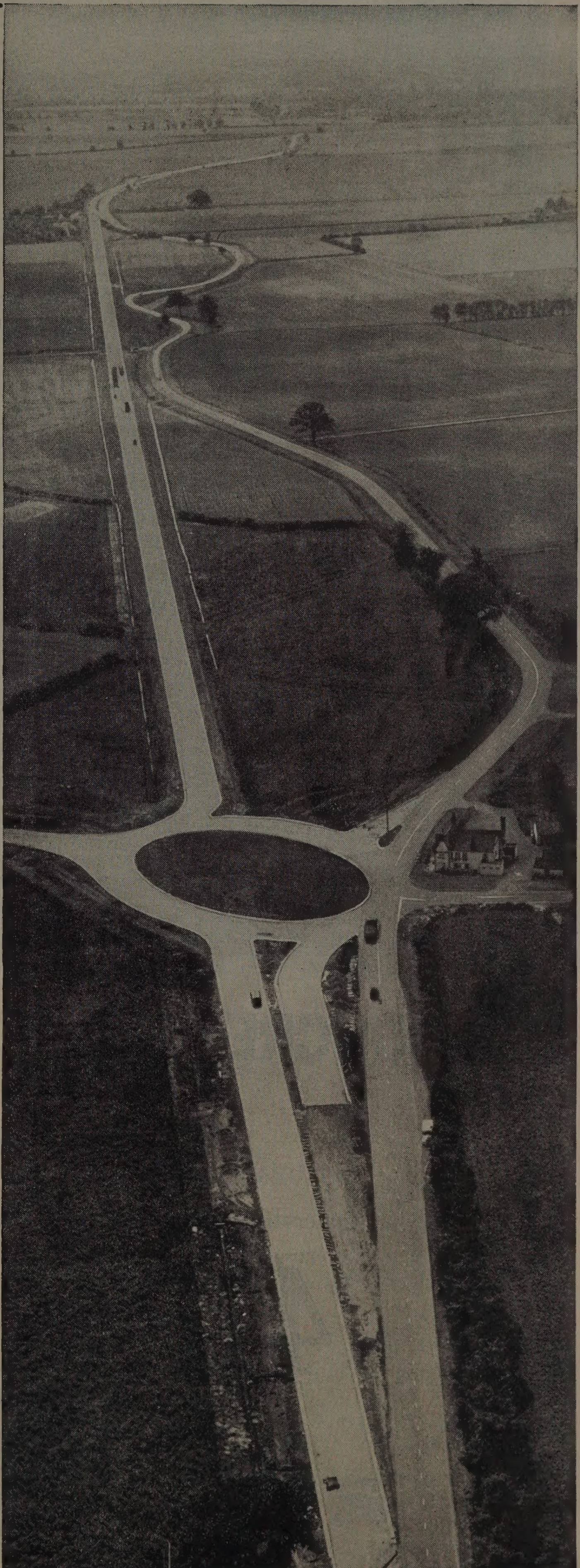
AT THE BRUSSELS FAIR

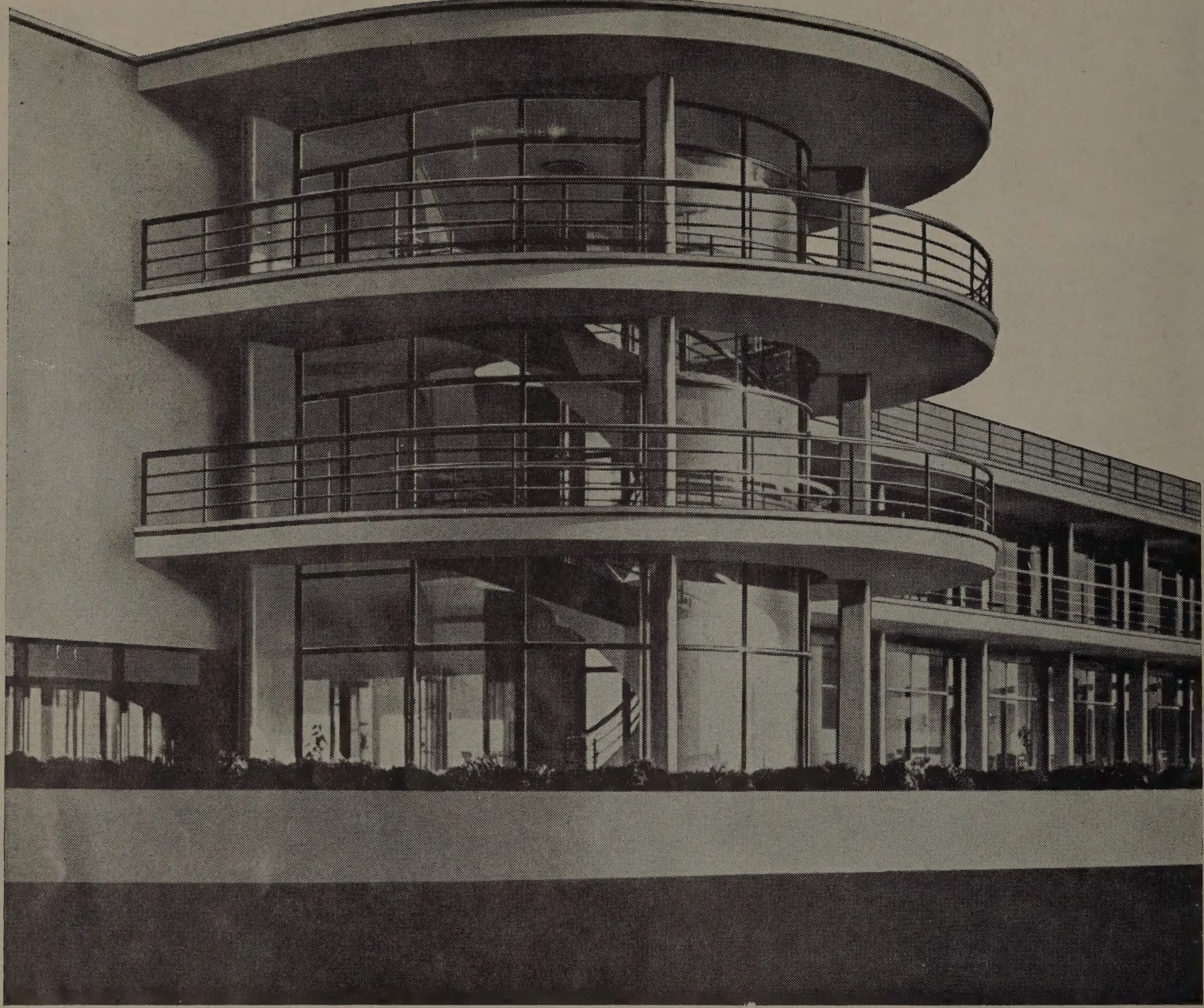




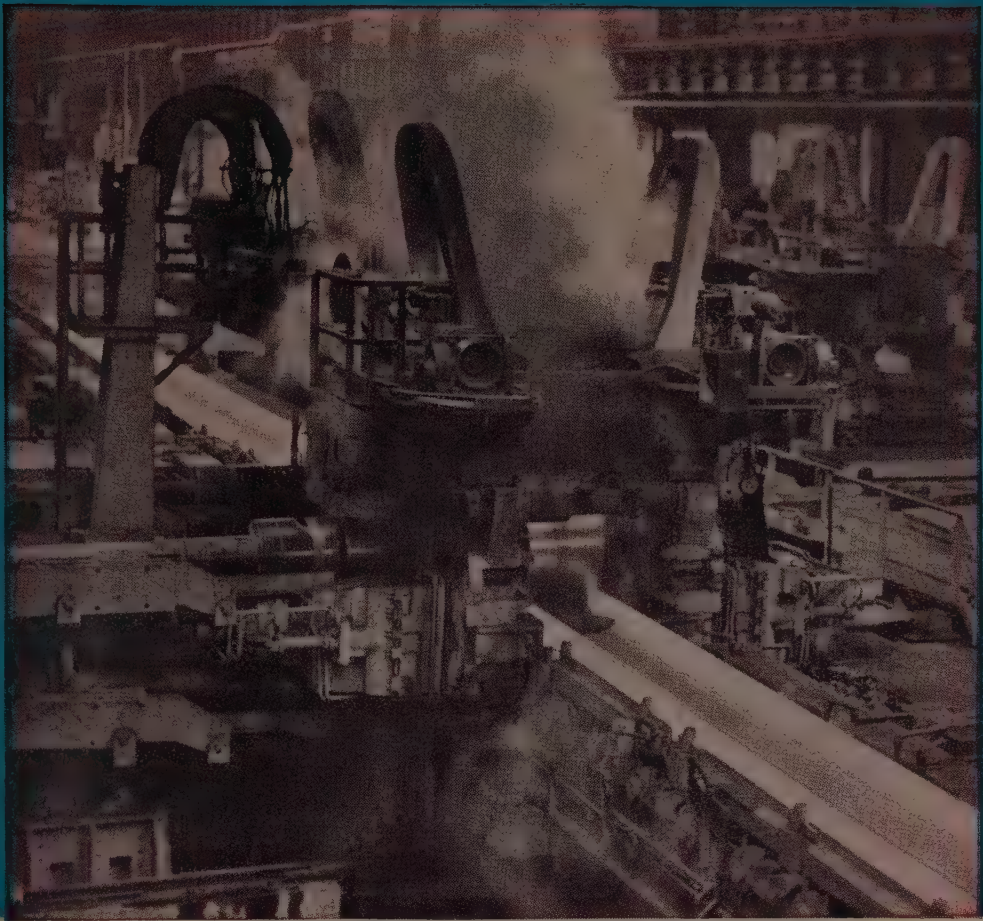


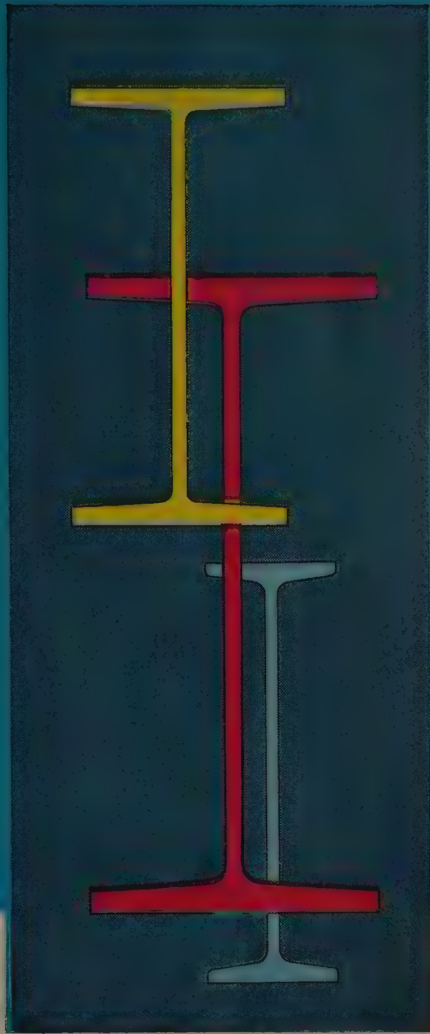
BRITISH CONSTRUCTIONAL STEELWORK ASSOCIATION, Artillery House, Artillery Row, Westminster, London, S.W.I






FLOWFORGE is approved by : The British Admiralty; Esso Petroleum Company Ltd.; I.C.I. (Billingham Division); I.C.I. (Alkali Division); I.C.I. (General Chemical Division); Kellogg International Corporation; Shell Tankers Ltd.; Shell Refining Company; George Wimpey & Company Ltd.; Mobil Oil Company Limited.
ALL USERS OF OPEN STEEL FLOORING CAN SAVE REAL MONEY
by specifying
FLOWFORGE
FORGE-WELDED OPEN STEEL FLOORING
Plain or Serrated edges (Plain edges illustrated)
BECAUSE:
SPECIFICATION
Flowforge is a monolithic open flooring product of EXCLUSIVE FORGE-WELDED CONSTRUCTION. It is designed to meet British and Foreign specifications. Twisted crossbars give a non-slip surface.
SERVICE
Large stocks of standard 20 ft. × 3 ft. panels are held ready for IMMEDIATE delivery. Delivery schedules for tailor-made panels can be arranged to meet site requirements.
SAVING
The exclusive manufacturing method ensures substantial savings in first cost—it is cheaper to buy Flowforge. Flowforge gives greatest covering area per ton; is easy to handle and fix; is completely adaptable to the job; has no crevices to hold moisture and start corrosion; is easy to clean, paint and maintain.
Our Advisory Service is available to solve your problems relating to open steel flooring—for original floors, mezzanine floors; stairways, fire escapes, gangways, bridges, catwalks, ships walk-ways, scaffolding platforms, earthing frames, etc.
Write for Flowforge Publication No. 181
Fisher & Ludlow Ltd
MATERIAL HANDLING DIVISION · BORDESLEY WORKS
BIRMINGHAM, 12 Tel : VIC 2371
Also at LONDON, MANCHESTER, GLASGOW, NEWCASTLE-ON-TYNE, BRISTOL, BELFAST and DUBLIN





'UNIVERSAL' BEAMS

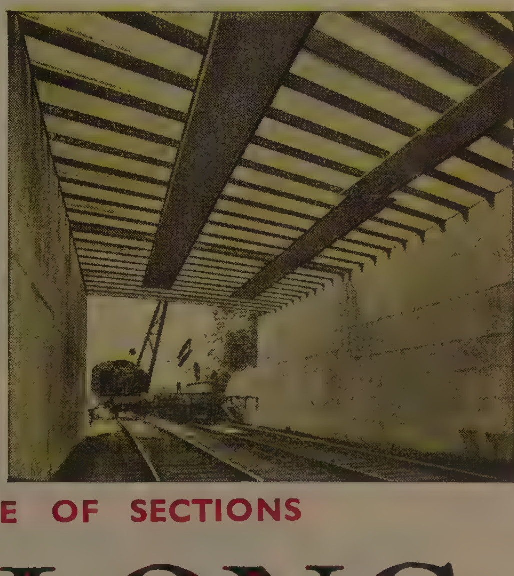
IN MANUFACTURE AND IN USE

Above in red, the new 36″ x 16½″ beam (shown in the rolling mill picture); in blue, the largest of the British Standard sections, 24″ x 7½″.

A bridge at Catterick (shown below) has just been built by Tees Side Bridge & Engineering Works Ltd., with spans of the new 24″ x 12″ Universal beams (shown in yellow) without plating.

Here is a 36″ x 16½″ 'Universal' beam passing through the finishing rolls of our new Universal Beam mill at Lackenby. It is the largest of our new range of sections — all carefully proportioned in the light of structural experience to simplify design and fabrication of steel structures.

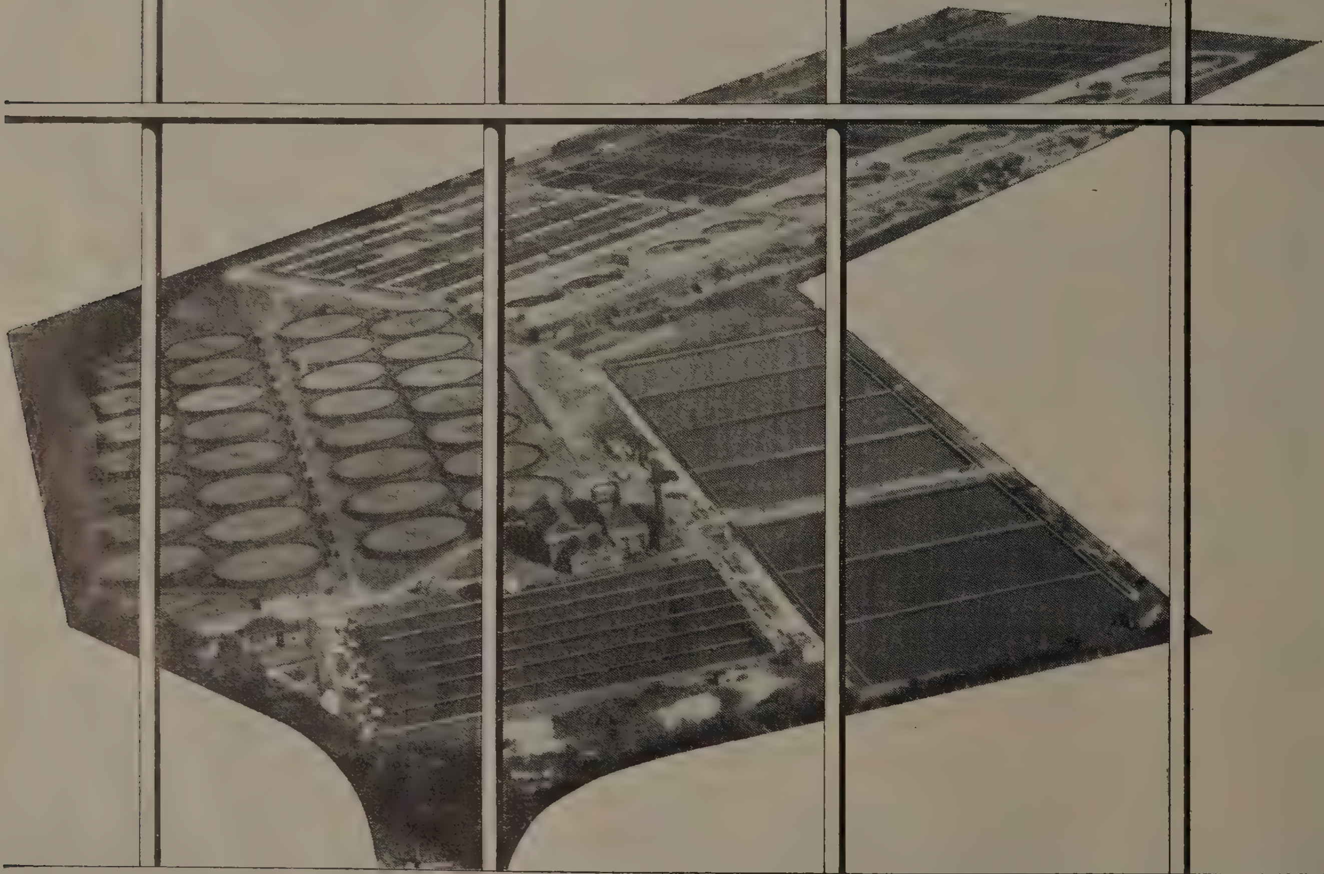
The new mill has important features which considerably augment its productivity and service to the industry: one is its construction with alternative sub-assemblies having rolls and bearings already mounted in interchangeable stands, thereby facilitating rapid changes. Another feature is the mill arrangement by which a beam or column section can be rolled in different 'weights' to suit different loads—yet without substantially affecting the overall dimensions.



The photograph of the Catterick bridge (shown at right), by courtesy of R. Sawtell Esq., A.M.I.C.E., County Surveyor, North Riding, Yorkshire C.C.

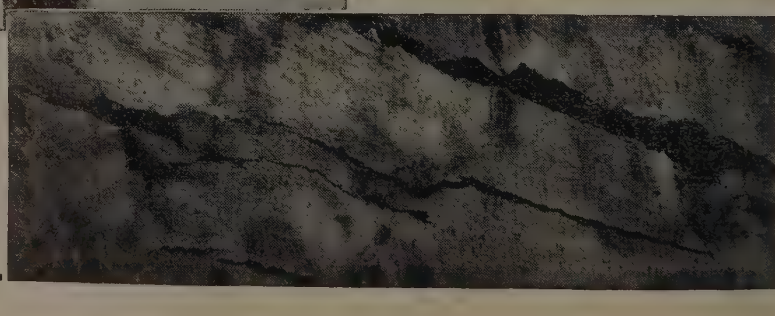
EARLY DELIVERY OF THE FULL RANGE OF SECTIONS

DORMAN LONG




Clearing the way for Daylight
NEWCASTLE-UPON-TYNE
BELFAST
HUDDERSFIELD
DUBLIN
MANCHESTER
LIVERPOOL
NOTTINGHAM
LEICESTER
BIRMINGHAM
BRISTOL
LONDON
HEYWOODS OF HUDDERSFIELD
Throughout the country many roofs in an advanced state of disrepair are being reglazed with HEYWOOD'S PATENT GLAZING. This replacement **does NOT involve the slightest hold up in production** but DOES involve many more maximum-light years, with increased output and considerably improved working conditions, decreased lighting costs and danger of damage to machinery and products, NO maintenance.
Quality of Glazing? Over 70 years stands surety for that!
Inspection and advice by experienced roofing engineers at the disposal of clients entirely without charge.
BAYHALL WORKS, HUDDERSFIELD. Phone Hudd. 6594 (5 lines)


* tailor-made to each job!
MULTIRAIL fabricated steel handrail standards have proved to be as rigid as the solid forged type, with the advantages of four ferrules enabling vacant ferrules to be used in carrying power lines, air and gas pipes, etc.
* MULTIRAIL
fabricated steel handrail standards
"SAFETREAD" FLOORING IS
welded for extra strength
Tailor-made and not just cut to fit, 'Safetread' flooring is no dearer to specify than ordinary steel flooring, but provides maximum strength with minimum of materials; non-skid surface; 82% light and air penetration; a neat-fitting, clean appearance.
* SAFETREAD
WELDED FLOORING
Write for detailed literature to :—
Allan Kennedy & CO. LTD.
MARITIME STREET · STOCKTON-ON-TEES



VOL. XXXVI. No. 12 DECEMBER, 1958

THE STRUCTURAL ENGINEER

THE JOURNAL OF THE INSTITUTION OF STRUCTURAL ENGINEERS

Founded 1908. *Incorporated by Royal Charter* 1934.

11 UPPER BELGRAVE STREET, LONDON, S.W.1. Sloane 7128/9.

CONTENTS

All Editorial communications should be addressed to The Editor, The Structural Engineer, 11, Upper Belgrave Street, S.W.1. All MSS. should be typewritten and algebraic signs and formulæ be indicated distinctly.

The Institution of Structural Engineers, whilst being at all times desirous of receiving communications from members and others, does not accept any responsibility for the opinion expressed by any individual Authors or Speakers

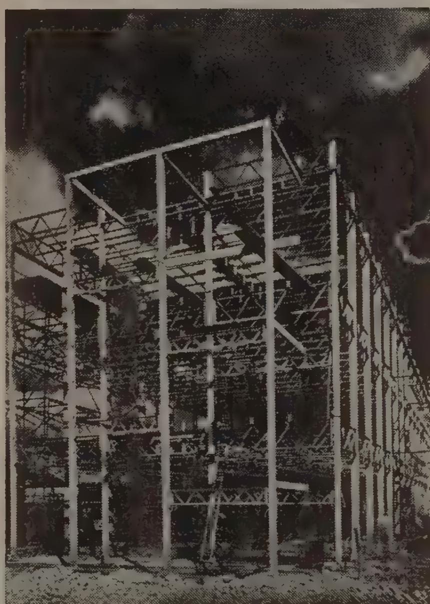
Annual Subscription Rate to the Journal £3 3s. post free.

Printed and Published for the Institution by JOHN MORRIS PUBLICITY LTD., Publicity House, 41 Streatham Hill, London, S.W.2, to whom all communications regarding advertisements should be addressed.

structural steelwork

The Bowater Paper Corporation Limited. "The Architects for the new Office Blocks at both Mersey and Northfleet designed for Lattice Steelwork on a modular grid which allowed service lines to be run between floor and ceiling and gave complete flexibility for internal arrangements.

Architects : Messrs. Farmer & Dark.



YORK. For the City of York a Grammar School. Sommerfelds designed the Steelwork on a 3′ 4″ modular grid allowing complete freedom for the Architect to use curtain walling and internal arrangements.

Architect : E. Firth, F.R.I.B.A., A.M.T.P.I., City Architect.

B.E.A. For this B.E.A. Building speed was the essence of the Contract. Sommerfelds designed the Steelwork and from unloading the first lorry on site to the completion of a 250-ton steelwork erection took 3 weeks.

General Contractors : Messrs. Richard Costain Limited.

I.C.I. For I C.I. a Laboratory Block. A multi-storey building with a height to eaves of 44-feet and uninterrupted spans of 50-feet on each floor. Deep Lattice Beams and light stanchions were used with considerable saving in steel requirements.

Architects : Messrs. J. Douglass Mathews & Partners.

Sommerfelds LTD. WELLINGTON · SHROPSHIRE

TEL. 1000

London Office : 167 VICTORIA Sᵀ S W 1 TEL: VIC. 8843 AND 1000

PRESIDENTIAL ADDRESS

By Gordon S. McDonald, M.I.Struct.E., M.I.C.E., M.I.Mun.E.

THE STRUCTURAL ENGINEER AT LARGE

Address given before the Institution of Structural Engineers at 11, Upper Belgrave Street, London, S.W.1, on Thursday, 2nd October, 1958.

I AM deeply conscious of the honour you have conferred upon me in electing me to the Presidency of this great Institution and I feel rather overwhelmed and humbled at the prospect of successfully following in the footsteps of so many brilliant men who have occupied this position in the past. It is indeed a source of great satisfaction to me personally that you have thought fit to choose for this office one who is a " provincial," and who commenced his association with this Institution through its Midland Counties Branch. All the members of that particular branch are extremely gratified that one of its Past Chairmen should have the distinction of being President in the Silver Jubilee year of the granting of our Royal Charter on the 4th May, 1934, particularly having in mind that twenty-five years ago Sir Arnold Waters V.C., D.S.O., M.C., a prominent personage in the Midlands and a close friend of mine, occupied this chair at that time. I appreciate therefore the heavy responsibility which you have entrusted to me in this outstanding year and for the next twelve months I shall dedicate myself to the best of my ability to the further advancement of the already high prestige of the Institution.

As you are all aware the fiftieth anniversary of the foundation of the Institution took place on the 21st July of this year and I owe a debt of gratitude to my immediate predecessor, the Jubilee President, Sir Alfred Pugsley, for his kindly co-operation in agreeing to the inclusion in my year of office of the many forthcoming celebrations, and I sincerely hope that he will be able to be present on all possible occasions. I would also like to pay a tribute to the loyalty, support and good wishes which I have received from all members of the Council and I would particularly like to express my deep appreciation of the efforts of all those energetic people, especially the Secretary and his staff, who have contributed so much to the planning and organising of the various meetings and functions taking place in the ensuing year.

I am anticipating with great pleasure my forthcoming visits to the various Branches and to meeting once again my many friends who do so much voluntary work in the interests of the Institution, which virtually could not exist without their willing and whole-hearted support. I send special greetings to our overseas members, who are always the subject of deep interest here in London and whilst it is obviously more difficult to maintain " personal " contact with them it is very gratifying to see the regular flow of correspondence reciprocating between London and all parts of the world. During the forthcoming year nothing would please me more than to see signs of the growth of the Institution by the formation of further sections or Branches abroad.

For some time now I have naturally been seriously meditating on the choice of a topic as a basis for this Address. I turned my thoughts back over the period of my own professional career and although I delved diligently in my memory for the recollection of some spectacular feat of structural engineering which I had achieved, alas, my search was fruitless! I found no Sydney Harbour Bridge, no Snowy Mountain Project, no Kariba Reservoir, but merely a wide-spread collection of works of minor stature which are nevertheless of major structural importance to the completion of the main project.

When I have been talking to other engineers about structural matters and particularly about this Institution, the remark has often been made to me " But you are a Civil Engineer!" which is usually followed by the question " How did you get mixed up with the Institution of Structural Engineers?"

My answer is a very simple one in that I realised many years ago that the art of Structural Engineering is the true basis of all engineering, because there is nothing in the world which, either by its very existence in its natural state or by some process of manufacture into something useful to mankind, is not in some way connected with structural engineering. The importance of our work must therefore never be under-estimated and the prestige of our Institution can only rise to an even higher level as a consequence of its magnificent service to the peoples of the world.

With these thoughts in mind I decided to formulate this Address on the lines of the wider issues with which we are concerned and I have therefore entitled it :— "The Structural Engineer at large."

Many members of the general public have no conception at all of the term " structural engineering " and unless they have had some engineering or scientific training it is very difficult to explain it to them. I would say simply that structural engineering is the process of fashioning various materials and fixing them together to form a permanent structure.

In order to achieve this objective, men in many different spheres of activity have to be included in the production team. There are the manufacturers with their extensive factories and their teams of experts : the building contractors with their wide knowledge of modern methods of construction : the independent consulting engineers with their unbiased views on economical technical design : and lastly but perhaps foremost in importance, the scientists and research workers who contribute so much to our overall knowledge of any particular subject.

All these different aspects of our work are truly represented among the 8,000 members of our Institution and with such vast resources of both theoretical and practical knowledge at our disposal we are confident that as an Institution we stand alone in being able to give sound advice on any particular engineering problem which may arise. This fact is being increasingly appreciated by Government Departments and various branches of industry since we are continually being consulted on technical matters affecting the whole future of the building world.

In this Institution we have always striven to maintain a balance of thought between theory and practice and you will find that the constitution of each of our committees is based on this fundamental idea. No praise can be too high for the work of the scientist whose expert knowledge is based on long and intensive research, but it is the practical man who has to put the theories to the test and only when he is satisfied with the results can we with confidence put any theory into general practice. I mention this because I have occasionally had a dreadful feeling that some young scientists spend a great deal of time in investigating problems which have been largely conjured up by themselves, and whilst these mental exercises are of great benefit to the student they sometimes tend to create an air of mystery which rather cramps the initiative of the designer or builder who has probably never even considered the problem until this minor uncertainty of design is placed in his mind. Fortunately such cases are rare, and great credit is due to our Institution as a whole for the work which is done in vetting and discussing these ideas before they are generally promulgated to designers. The modern scientific approach to the solution of our problems must sometime make us all wonder how the giants of the past, without the aid of up-to-date science and research, contrived to design and build the magnificent structures still standing today, for those men knew only by instinct whether their creations would stand the test of time. I think that even today the greatest engineers are still finally guided by their own convictions based on experience even when faced with a mass of technical and scientific information, and I sincerely hope that this personal element in making final decisions will always stay with us, in spite of the sometimes frightening array of electronic computers and other "press-button" mathematical instruments.

Fig. 1.—The Restoration of Dangerous Buildings

In the engineering world the structural engineer is playing a role of ever increasing importance, for his work is an essential part of any section of industry or commerce which concerns the building of a structure. For example the gas engineer has his problems in the construction of foundations and superstructures for retort houses, gasholders, elevators, coal bunkers and a host of other structures which are related to the production and distribution of gas. Likewise the electrical engineer could not function without power stations, cooling towers, and bases for heavy machinery, all of which directly concern the structural engineer. Aircraft must have their aerodromes, hangars and service buildings, to say nothing of the skill and research embodied in the actual construction and testing of the craft themselves. Ships, apart from the fact that each vessel is a structure in itself, must have shipyards, docks, harbours, wharves, lighthouses and anchorages in order to operate successfully and economically. No modern railway system can exist without its bridges, stations, warehouses, engine sheds, repair shops and numerous other buildings. The mining industry depends essentially on efficient pit-head gear, bunker and handling facilities. So one can go on enumerating one industry after another and in every case the work of the structural engineer is evident in some phase directly connected with its operation.

One of the most important spheres of structural engineering as far as industry is concerned is, of course, the construction of modern factories, where the prime factor is the provision of the maximum availability of floor space, together with first class arrangements for heating, lighting and ventilation. The structural engineer of today is highly appreciative of these problems and in his designs he strives to limit his columns, stanchions and supports for his superstructure to the absolute minimum in size and number. The benefit of this approach to factory design is amply demonstrated in the increased output per square foot of floor area which inevitably occurs when the operatives are working in such favourable conditions as compared with the cramped working conditions of the past. The efforts of the structural designer in producing new methods of roof construction and framing units have contributed largely to the efficiency of the modern factory, but I fear that these efforts are not appreciated by all manufacturers, some of whom still seize on any available floor space for yet another machine, until the factory is so overloaded with motors, belting and shafting that conditions deteriorate rapidly and relative output drops considerably.

The beneficial work of the structural designer is much more obvious in the foregoing sphere of activity than in other fields of engineering where his influence is not quite so apparent since it is perhaps overshadowed by the considerations involved in the main project, which may be of immense benefit to the general public, but which has no direct bearing on any particular industry. I refer to matters such as main drainage, flood relief, sewage treatment and water supply.

To the average person the construction of a sewer seems to have little to do with structural engineering and indeed when operating in open country there are few problems of that nature encountered. Where, however, one is dealing with a densely built-up area and the sewer has to be laid at considerable depth through congested streets then the overall picture is

Fig. 2.—Construction of Sewer and River Wall

Fig. 3.—Sewerage—Sewer Construction in Tunnel

a very different one. Here the engineer is confronted with many cases where special designs or precautions are necessary in order to protect adjacent buildings from damage or possible collapse and such measures are nearly always carried out while the premises are still in occupation. It says much for the skill of the engineers that we seldom hear of the collapse of a building with the consequent injury or loss of life to its occupants. During the progress of the work each building presents its own particular problems, especially in the case of very old structures about which little information is available. One often finds that the footings of a building are either non-existent or at such a level or on such weak subsoil that extensive underpinning has to be carried out and great skill and experience is necessary in order to avoid settlement or collapse during the progress of the work. I would say that here we see the structural engineer at his best in coping with the many intricate and possibly dangerous problems encountered in providing adequate support to the buildings.

Flood relief works have again two entirely different aspects. In rural areas they consist largely of the dredging of rivers, the forming of protective berms and the construction of control sluices and pumping stations. In our larger towns, however, we find that the industrial concerns have in the past sited themselves on the banks of any available stream or watercourse, obviously so as to enable them to obtain readily a supply of water for the particular manufacturing process in view, since in those days there was no efficient system for the distribution of water. During the course of time the towns have spread themselves around these localities and the resulting concentrated discharge of rain-water to the rivers causes flooding, with dire consequences to the industrial area and ultimately to the surrounding residential district. Since the watercourse is confined between the walls of buildings and cannot be easily widened, the only economic solution of the problem is to deepen the bed in order to lower the ultimate flood level. The problem now becomes a matter for the structural engineer, who has to devise methods of relieving the side-walls of the river from loads imposed within the factories and of underpinning them to a depth of perhaps four or five feet or more. Inevitably one finds that the old side-walls themselves are very slender, and I have seen cases where, by all standards of stability, the walls should have collapsed long ago, and it seemed that the only reason for their continued existence was by " force of habit!" One can readily appreciate the dangers of dealing with these old structures particularly when the work is constantly menaced in wet weather by a rise in water level in the river of some six feet or so in twenty minutes, and it is only the skill and experience of the structural engineer which can cope with such conditions without running the risk of total collapse of the structure with its serious consequences of damage to expensive machinery and possibly human beings.

The design of a modern sewage treatment works demands, initially, a knowledge of many subjects completely foreign to the structural engineer and, where adequate site space is available and there are no specific problems such as the treatment of difficult trade waste, the construction of the various units is of a comparative easy structural nature, entailing the use of mass brickwork or concrete in its simplest form. If, however, through restriction of space or the complicated nature of the sewage to be dealt with, a particular form of treatment is required, then the various units have to be designed specially in order to house the necessary operational plant. In such cases the required shape, loading, and strength of each unit nearly always results in the choice of reinforced concrete as the medium of construction and here the engineer has a difficult task in designing the structure in order to satisfy both the physical conditions, such as subsoil water-pressure etc., and also the requirements of the plant manufacturers. Without the structural engineer's skill this task would be impossible and though much of the completed work is often buried and out of sight, it still gives him great satisfaction to see eventually the plant in full operation.

With the growth of industry and the ever increasing improvement of our standards of living more and more water is in demand and the harnessing of the natural supplies, both surface and underground, is a fascinating field of work for the engineer. Inevitably there is somewhere in the line between the collecting and delivery points where an expert knowledge of structural engineering is essential. The design and construction of impounding reservoirs has always been a specialised subject and the modern hydro-electric scheme presents even more intricate problems than hitherto. The building of the main dam in itself is a masterpiece of structural engineering, to say nothing of the feed culverts, control gates, power stations, pumphouses and all the other complicated structures which are necessary for the completion of the project. In the design and construction of impounding reservoirs we have made great strides in recent years in the application of a subject which has become extremely important namely the study of " Soil Mechanics." It is possible today to build a water retaining dam purely of consolidated earthworks and the success of this method must be attributed largely to those eminent scientists who have for so many years delved into the mysteries of soils, their proper mixing and compaction. Surely this is a perfect example of combining " theory " and " practice " in order to produce an inspiring result.

The tapping of underground water supplies entails the sinking of boreholes and the construction of pumphouses and chambers, usually with heavy foundations and complicated superstructures, in the design and construction of all of which structural engineering plays a leading part. Further down the supply line we come to the essential local reservoirs which conserve a supply for a particular area. Whether open or covered, below ground or elevated, these reservoirs present problems which are essentially within the scope of the structural engineer, who has to adapt his design to the particular conditions of the site which itself is usually dictated by the hydraulics side of the scheme. Reinforced concrete in all its different aspects is a popular medium of construction for these reservoirs and the required degree of water-tightness necessitates great care and skill on the part of the designer, perhaps more so than in the case of any other structure.

I hope that the few examples I have quoted are sufficient to stress the importance and all-embracing necessity for the work of the structural engineer in which our great Institution plays so prominent a part.

The prestige of any Institution cannot be measured by the value of its monetary reserves nor by the size of its membership roll, but rather by the service which it renders to the community at large, and in this respect I claim that our Institution is unique. In these days of specialisation no organisation or body can continue to function properly unless it has a definite and distinct purpose of its own. Like several other Institutions, ours is aptly named and its very

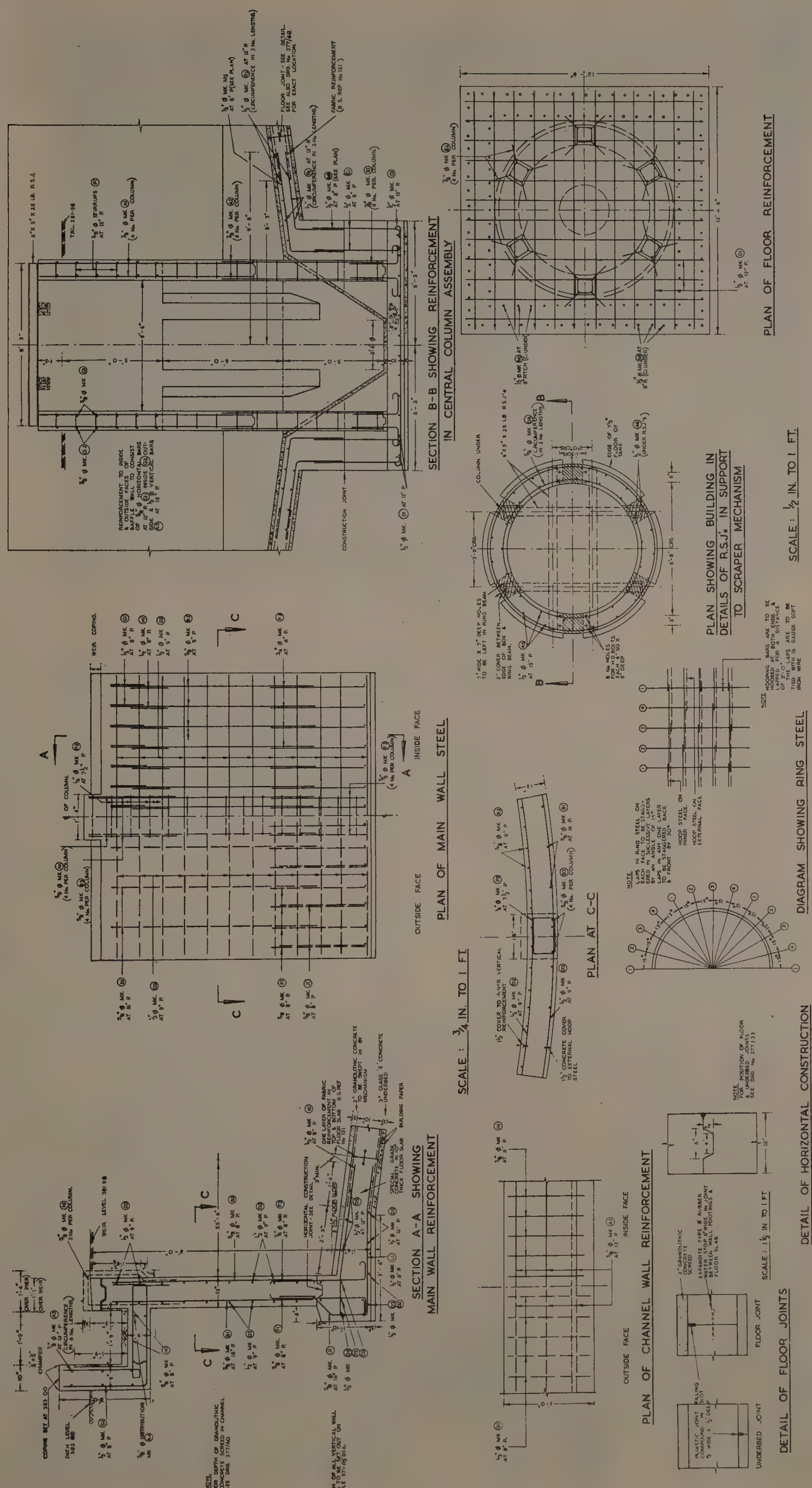


Fig. 4.—Sewage Treatment Works—Circular Tank Construction

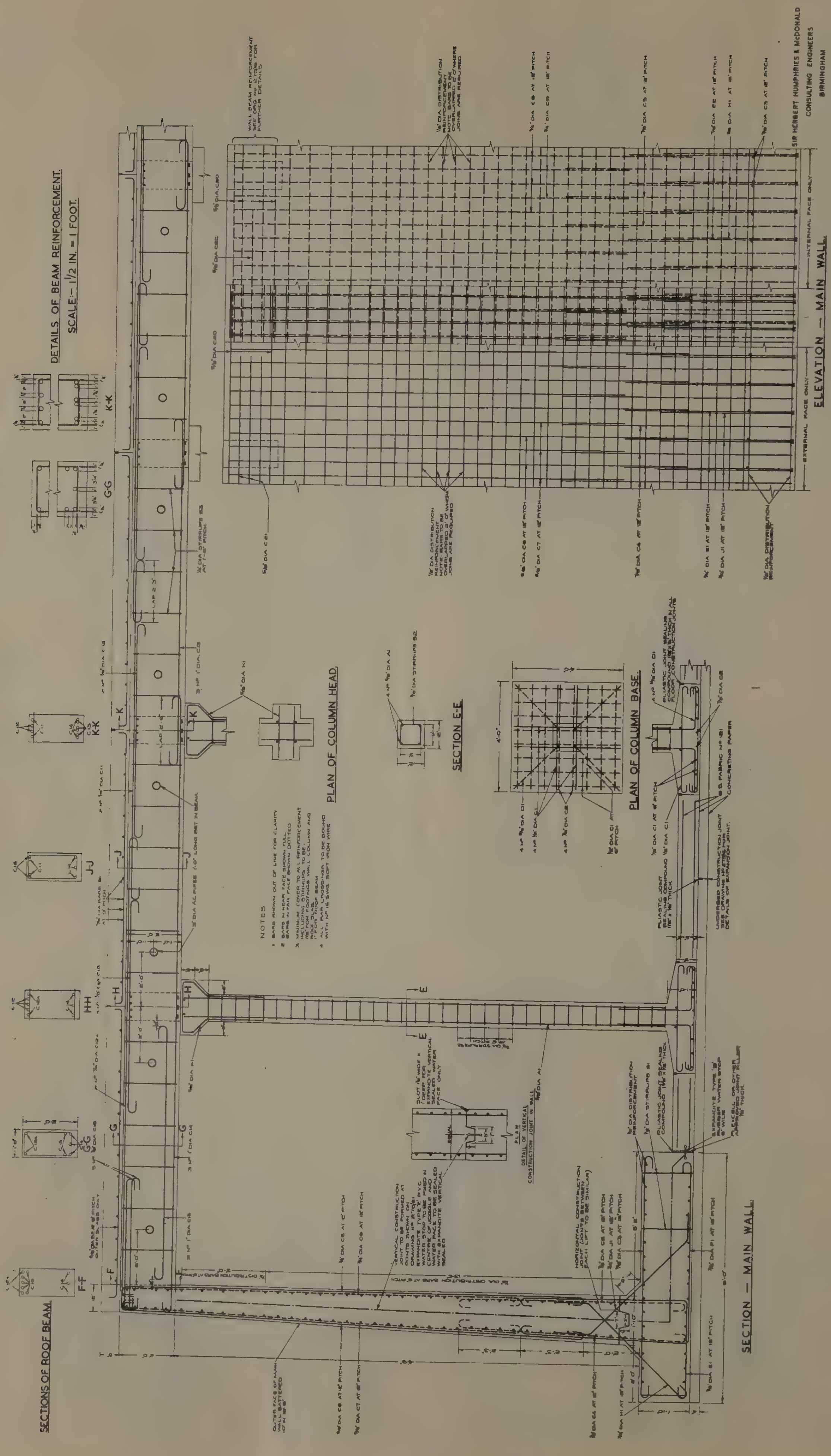


Fig. 5.—Water Supply—Reservoir Construction

Fig. 6.—River Improvement Works

title affords no confusion in one's mind as to its purpose—the study of structures. For the past fifty years it has never deviated from this set idea and I cannot see any possible prospect in the future of segregation or disintegration taking place within the constitution of the Institution.

I have heard it mooted on several occasions that too many Engineering Institutions exist today and that an enormous amalgamation should take place so that we all speak to the world with one voice, but such a step would, in my opinion, lead to utter chaos and the foreigner would be even more puzzled than he is today as to the meaning of any British professional title. I cannot conceive that any single professional body could completely control so many specialised branches of engineering, particularly from the point of view of providing adequate technical education. I feel sure that our present high standard of qualifying examinations would rapidly deteriorate and our future engineers would be in the category of " Jack of all trades and Master of none." There may possibly be some room for a Joint Council of Chartered British Engineers, similar to the Engineer's Council for Professional Development set up in the United States of America, but such a body should only have consultative powers on matters of general national policy and should in no way interfere with the internal affairs of any particular Institution. If such a body were formed I have no hesitation in suggesting that our Institution, in view of the services rendered by structural engineers to members of all other professions, should be strongly represented and should be in the forefront of leadership.

Whilst I deprecate any amalgamation, I am most anxious that we shall collaborate to the utmost possible degree with other technical bodies whose work is complementary to our own and I would mention in particular the Royal Institute of British Architects. Modern buildings being constructed in this country today are undoubtedly a credit to the Architects concerned. The careful planning of factories, houses, hotels and other buildings presents many problems to the Architect, who has to produce an economic design, and at the same time incorporate all the necessities for comfort and ease of working, together with the essential beauty of appearance which is his ultimate aim. The design of the basic structure itself has now become a highly specialised job and here the structural engineer reigns supreme, since his expert knowledge and careful attention to detail " dovetails " perfectly with the work of the Architect and both parties should be highly satisfied with the results of their team work.

The future of our Institution lies in the hands of the younger members who are joining us in ever increasing numbers and it is our duty to encourage them in every possible direction. No more outstanding example exists of the general interest in the youth of today than the encouragement and leadership of His Royal Highness the Duke of Edinburgh, who has recently so kindly agreed to become an Honorary Member of our Institution, and it lies with us to emulate his stirring example. We ordinary members of shall I say the " old school " can do much to assist the young man by affording him every opportunity of gaining that practical experience which is so essential to his future career. All too often are we accused of looking askance at the immense mass of technical knowledge which the young man possesses and he, on the other hand, is apt to regard us as "old diehards" who will not accept the modern theories. Much can be done to bridge this gap by the exercise of great tolerance on the part of both sides, and the combination of the experience and coolness of the older man with the up-to-date knowledge and verve of the younger man will produce astonishing results.

Now a brief word on educational matters, in which I have been very interested over the past few years. We have already revised our Examination Syllabus in the light of modern requirements as to the standard of technical education, and this has been propagated amongst the various teaching establishments throughout the country. In this connection I would like to

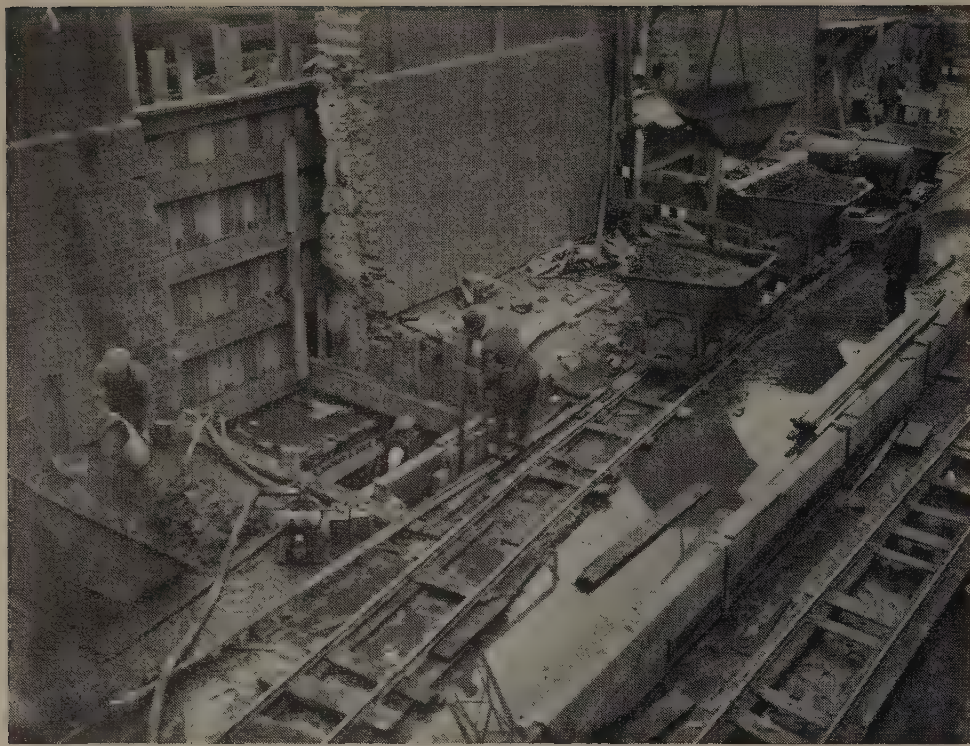


Fig. 7.—River Improvement Works

convey to those academic gentlemen, who have worked so long and so arduously on our committees, the grateful thanks of the Institution for their expert advice and criticism in framing the new syllabus, which cannot but enhance the professional standing of all our members. Throughout my period of service on the Council I have been extremely impressed with the attitude of friendly and close liaison between the Institution and the teaching profession, which has resulted in the formation by the Universities and Colleges of so many different kinds of courses of education to suit the needs of our young engineers. I am particularly interested in the setting up of Readerships or Chairs of " Structural Engineering " and I can assure our friends in the Universities and Colleges that any request from them for advice in this direction will be welcomed by the Council and the Institution will do all in its power to produce the desired result. Unfortunately, the Institution is in no position to provide the necessary finance for this purpose, and it is only by the ready aid of industrial concerns that we can be enabled to use our influence for the provision of adequate technical education, so that the ever increasign demands made by industry for trained young engineers can adequately be met.

As an Institution we have passed through fifty years of progress in technical knowledge and it is difficult to forecast what the next fifty years will produce. Those people who are perhaps better placed than I am to judge, say that space travel will become a fact within the next decade, and one can imagine the whole host of problems this will present to the structural engineer. It is possible that some entirely new material will emerge, which will revolutionise our present standards of strength, weight and methods of construction. Gravitational problems will cause a great deal of thought and research to be carried out, since if we are to design an object capable of self support in the earth's atmosphere and at the same time capable of transporting itself through space to another planet where gravitational and atmospheric conditions are entirely different, then the structural engineer has a great deal of investigation to pursue. Yet I have every faith that when the scientist presents his problems to the engineer an answer will be found, and perhaps in the reasonably near future, man will be able to pursue with perfect safety his insatiable curiosity by making adventures into outer space.

Our kindred professions in the engineering world are today turning more and more to the structural engineer for advice. Faced as we are with the problems of atomic power and its propagation for industrial purposes, although the scientists must necessarily lead in this modern field, it is the structural engineer who supplies the knowledge and skill in designing the various components to house the scientific apparatus, and here again the Institution as a whole is ready and anxious to play its part in co-operating with other bodies in collecting and disseminating this specialised knowledge throughout its membership.

In conclusion, I am sure that we are all looking forward with great interest to our Jubilee Conference in London. The papers being presented cover a wide field and I am confident that they will serve to demonstrate how wide-spread and all-important is the art of structural engineering. Even more striking will be the demonstration of the collaboration and team work between the scientist and the practical engineer and how the work of each is so important to the other in both design and execution of the work. This " getting together " of our members and friends will do a great deal towards moulding the future of the Institution on the right lines, and will do much to spread that atmosphere of friendly discussion and argument which has always been prevalent in this Institution and which has done so much to cement its members together in one sound body.

Let us go forward to the future with the utmost confidence and unite in saying " Long live the Institution of Structural Engineers! "

The Design and Construction of Pelham Bridge, Lincoln*

By S. M. Reisser, B.Sc.(Eng.), M.I.Struct.E., A.M.I.C.E., M.Inst.W.,
K. M. Wright, B.Sc.(Eng.), A.M.I.C.E., and D. Bolton, B.Sc.(Eng.)

Introduction

The ancient City of Lincoln has been renowned for hundreds of years for its beautiful cathedral and the many examples of Roman remains which are to be found within its boundaries. Since the advent of the railways, which resulted in level crossings across its main North and South roads, it acquired another claim to fame of a different nature—in the shape of unparalleled traffic problems.

The High Street which includes two level crossings and the beautiful Stone Bow, a narrow arch capable of carrying only a single line of traffic in close proximity to a main cross road, is not conducive to a speedy crossing of the City by either local or through traffic. The parallel road to the east is cut by only one level crossing, but its effect on traffic can be clearly seen from the 1956 traffic figures : in that year an observation taken over 16 hours showed that 10,000 vehicles used the crossing and the gates were closed for 33½ minutes in the hour. Any further remarks on the subject would clearly be redundant.

A number of possible solutions of the problem were considered for some time in the past, and some preliminary work was in fact carried out. The present scheme, which makes use of the work already done and which also fits in with the proposed general development of the City, was approved in principle in 1948 and received its blessing in the shape of a 75% grant by the Ministry of Transport and Civil Aviation in the summer of 1954. The design was presented to the City Council in January 1955 and it was agreed to adopt the unusual course of appointing separate main contractors for the steelwork and the civil engineering work because of protracted steel deliveries and the need to have the bridge open to traffic as soon as possible. The contract for the steelwork was let to the Butterley Company in September 1955, that for the civil engineering to Tarmac Limited in March 1956. Work on the site commenced in the spring of 1956, the first lane was open to traffic in December 1957, the second lane in April 1958, and the bridge was formally opened by Her Majesty the Queen on the 27th June 1958. A general view of the bridge is shown in *Fig.* 1.

General Considerations

The layout of the bridge had to be chosen with due regard to the demolition of property which could not be avoided, and the maintenance of both road and rail traffic throughout construction was a basic requirement. The new bridge, moreover, had to fit in with the proposed development of the City and incorporate the local industrial access requirements. In addition, the siting as well as the aesthetics of the bridge had to be approved by the Royal Fine Arts Commission. It is interesting to note that the layout finally adopted differed very slightly from that originally intended by the City Engineer and Surveyor.

The design, of course, besides being to some extent influenced by ground conditions, had to provide the standard clearances of the British Railways and comply with the Ministry of Transport's requirements concerning gradients, visibility, loads, stresses, carriageway, widths etc. Economy of costs was a further paramount consideration. Although some of these requirements at first appeared to be conflicting, it has in fact proved possible to reconcile them.

General Arrangement

The bridge which is 1,470 ft. long overall, has a width of 68 ft. consisting of two 24 ft. carriageways separated by a 4 ft. central reservation strip and an 8 ft. walkway on each side cantilevered off the main structure.

The general arrangement of the bridge and approaches is shown in *Fig.* 2 and it will be seen that three different types of construction have been adopted. All had to comply with the vertical curve determined from the Ministry of Transport requirements concerning gradients and visibility and the horizontal curve dictated by the layout, but the nature of each section was decided upon as under.

(*a*) *Railway Spans*

The layout of the main line tracks had to be regarded as a fixed factor and this dictated spans of some 90 ft. for the two central spans over the railway. The vertical railway clearances necessitated a low construction depth and the impossibility of any interference with the railway traffic called for ease and speed of erection. Considerations of minimum costs of maintenance and the importance of appearance for a bridge in the centre of the city were also added to the physical limitations of the site, and design comparisons were made with these factors in mind.

It was found that a system of continuous all welded girders with a composite concrete deck could reduce the construction depth to 3 ft. 4 ins. at the centre and would best meet the remaining requirements. The complicated nature of the movement of the continuous girders at the intermediate supports and the abutments due to the curved layout of the bridge in both plan and elevation, did cast some doubt as to the suitability of the system, but the difficulty was overcome by the design of a special type of rubber bearing which could easily accommodate the calculated range of rotation and expansion caused by both loading and temperature conditions. Continuous all welded girders with a composite concrete deck were therefore adopted for the railway spans.

* *Paper to be read before the Institution of Structural Engineers at* 11, *Upper Belgrave Street, London, S.W.*1., *on Thursday,* 11*th December* 1958 *at* 6 *p.m.*

Fig. 1.—General View of the Bridge

(*b*) *Approach Spans*

It was found that a continuous reinforced concrete slab design of a span of 30 ft. and 1 ft. 9 ins. thickness at the centre provided an economic solution at heights of over 11 ft./12 ft. In addition, the profile of the slab haunched at the supports matched the appearance of the railway spans and the simplicity of the arrangement was deemed to be desirable from the point of view of construction in view of the double curvature of the deck.

(*c*) *Embankments*

The approaches to be carried on fill had to be confined in width over most of their length because of adjacent roads and property. Only at one end was it possible to accommodate the spread of the normal slope of the fill. The lengths of the fill approaches were decided from a comparison of costs between the retaining walls with fill and the 30 ft. approach spans construction—the latter, as already mentioned, being found more economical at heights of over 11 ft./12 ft.

(*d*) *Foundations*

A series of borings were made and showed that the ground conditions necessitated the structure to be supported on piles transferring the load to the grey clay generally encountered at about 40 ft. below ground level. It was appreciated that the site conditions at the time when piling was in progress would be unsuitable for manoeuvring a piling frame—since demolitions of exisiting property (carried out by the City Engineer & Surveyor) would be going on at the same time and could not be done in a sequence calculated to clear the site progressively from end to end. Moreover, it was known that numerous basements, underground petrol tanks and cellars would be encountered, and in situ bored piles utilising light easily handled rigs

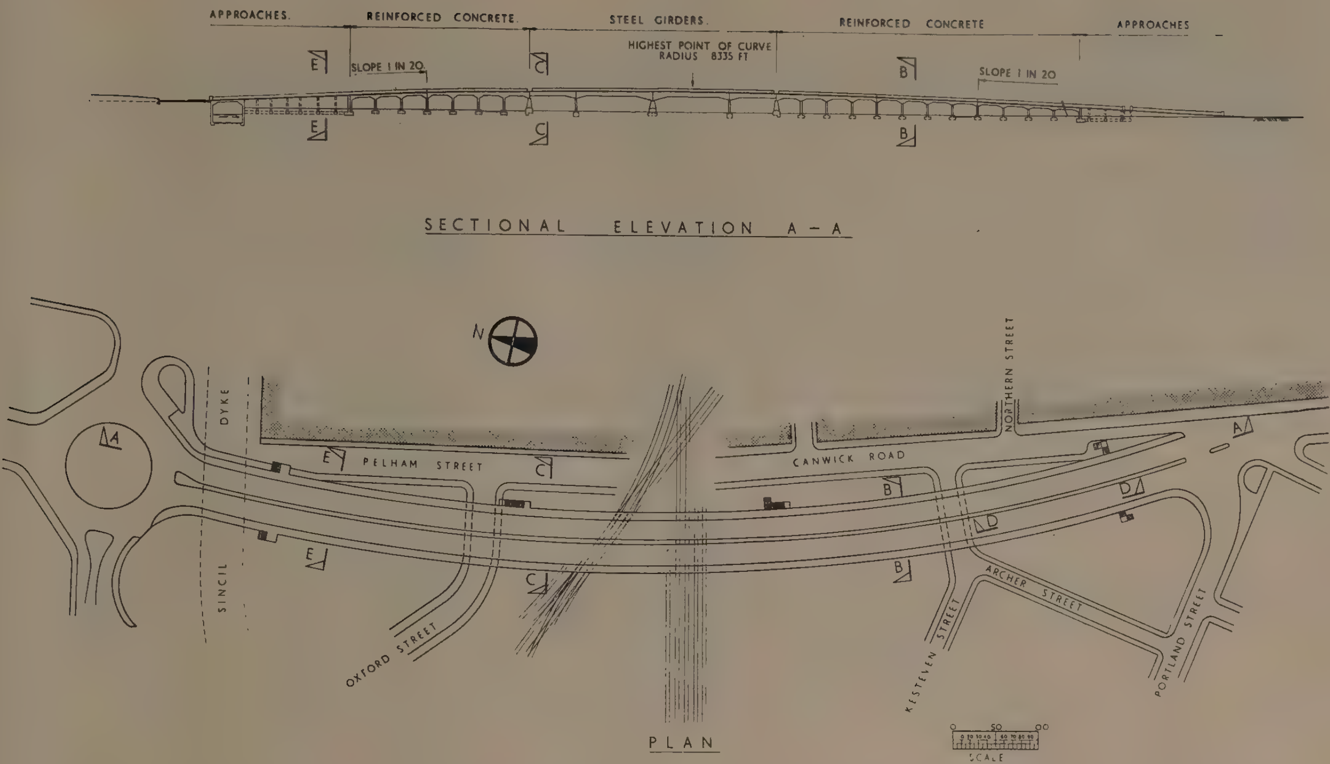


Fig. 2.—General Arrangement of the Bridge and Approaches

were consequently specified. The load bearing capacity of each pile in a group was fixed at 50 tons on the information obtained from the soil investigation.

The pile caps were tied together by precast beams of slender cross sectional dimensions with ordinary plain mild steel reinforcement and were designed to resist the horizontal forces without transferring them to the piles.

The retaining walls were also supported on piles and were connected by a system of post-tensioned tie beams designed to prevent spread and also resist the overturning forces acting on the walls.

Loads and Stresses

The bridge was designed to the standard Ministry of Transport HA loading, but was also checked for the abnormal 180 ton load. The walkways were designed for 100 lb./sq. ft.

The stresses for the concrete complied with the Ministry of Transport's Memorandum on Bridge Design and Construction No. 577, and those for the steel were in accordance with B.S. No. 153—Parts 3A and 3B.

Design

(a) Railway Spans

The four continuous all welded composite spans measure 55 ft. 3 ins., 89 ft. 6 ins., 89 ft. 6 ins. and 55 ft. 3 ins. on the centre line of the bridge. The width of the bridge is carried on eight girders at 8 ft. centres, *Fig.* 3, the outside girders carrying the cantilever walkways. The deck slab is 9 ins. thick throughout and the steel girders are 2 ft. 7 ins. deep at the centre. The girders are haunched to a depth of 5 ft. 11 ins. and 4 ft. 5 ins. over the central and outer supports respectively, a parabolic transition being used. To accommodate the horizontal curve, changes in direction of the continuous girder occur over the supports.

The top and bottom flanges are of notch ductile steel and of a constant width of 9 ins. and 18 ins. respectively. The maximum flange thickness is 2 ins. The effective section is calculated as a "T" beam and $1\frac{1}{4}$ in. diameter M.S. reinforcement is used as additional top flange area.

The 180 tons abnormal load is spread between the main girders by means of intermediate transverse joist frames, the load distribution in the grillage having been analysed by the Morice & Little's method.*

No corrosion allowance was made in the thickness of the steelwork which was metal sprayed by the Schori process to a thickness of 0.004 ins. The top flange, which is in contact with concrete, was sprayed with zinc and the remainder with aluminium.

The recent investigations carried out in the University of Illinois were made use of in the design of the 6 in. × 3 in. channel shear connectors and the concreting sequence for the deck slab was specified to ensure no overstressing of the steelwork during construction. In this latter connection it will be remembered that considerations of railway traffic precluded the use of any temporary props.

*" Load distribution in Prestressed Concrete Bridge Systems," published in " The Structural Engineer " March 1954 and January 1955.

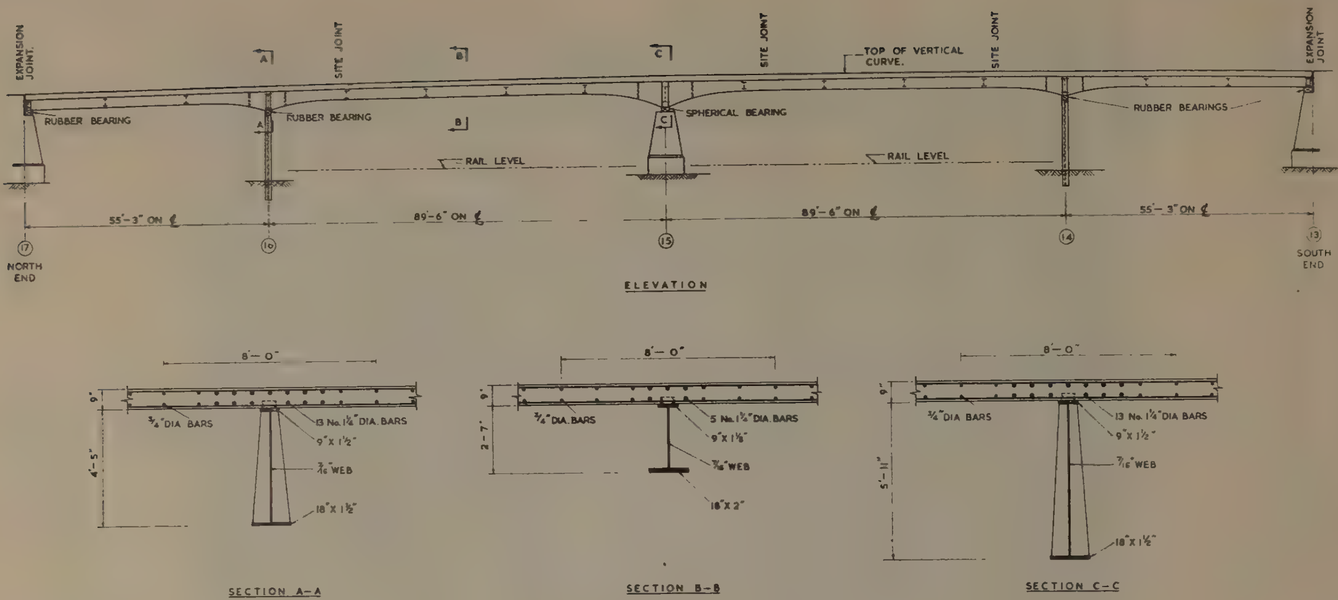


Fig. 3.

The expansion of the steel spans takes place outwards from the central pier and expansion joints in the deck slab occur over each abutment. The steel spans are anchored to the solid centre pier by means of spherical bearings which allow rotation, but no horizontal or vertical movement. A specially designed rubber bearing, *Fig.* 4, is used over both intermediate supports and abutments, and this is believed to be the first application of the use of rubber for bridge bearings in this country.

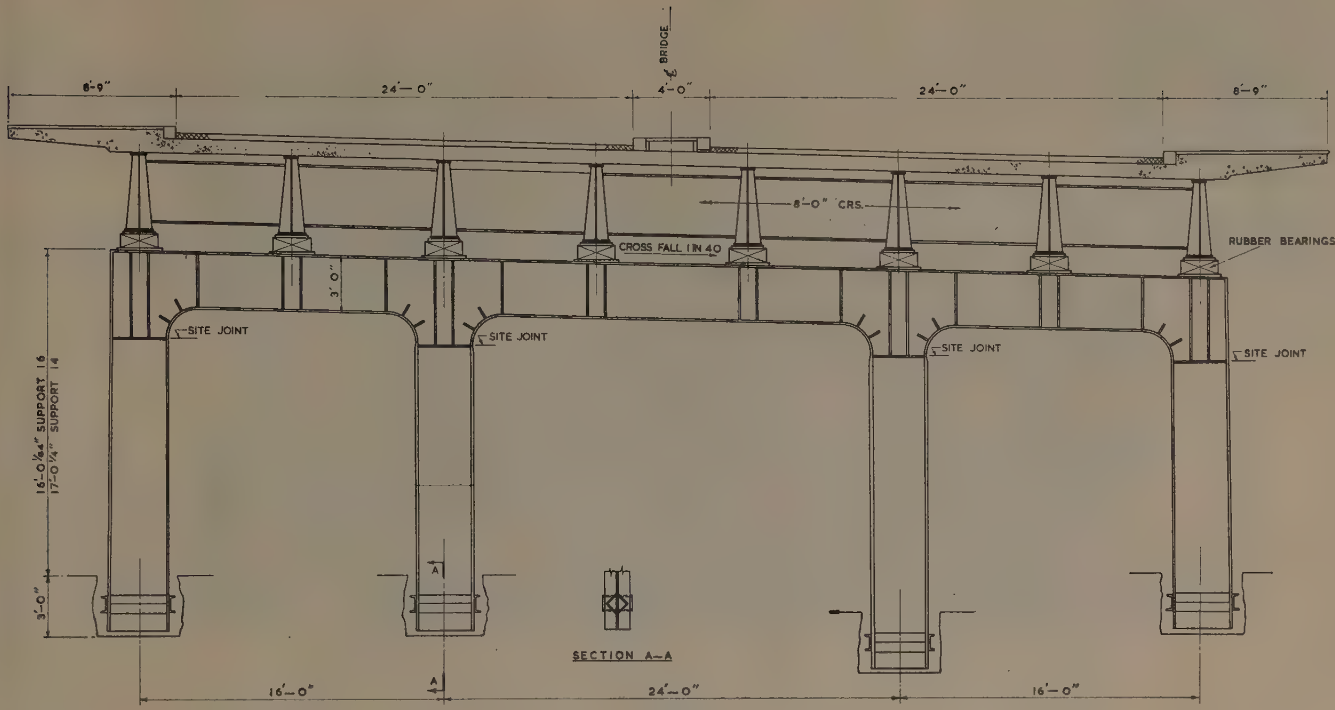
Fig. 4.

The main advantages of this type of bearing are full efficiency without any need for maintenance and the possibility of designing the bearings to take up the required relative movements in any direction. The bearings consist of a series of steel plates imbedded in rubber—the bearing area, the number of steel plates and the thickness of rubber between the plates determining the compression and shear rates. Thus in the case of the Pelham Bridge the rubber bearings measure 24 ins. × 16 ins. × $7\frac{1}{8}$ ins. and have a compression stiffness of 1,200 tons with a shear loading of 9.4 tons per inch.

The intermediate supports consist of three span steel portals, *Fig.* 5,—the portal legs being cast into pockets left in the pile caps without the use of any base plates, gussets or holding down bolts. The vertical loads are taken in bearing and the portals, which were designed ahead of the rubber bearings, were made sufficiently flexible to take up the full expansion in bending—this precaution having been taken to allow for the substitution of traditional rocker bearings in the event of any unforeseen difficulties arising either in the design or the manufacture of the rubber blocks. None in fact was encountered, but it should be noted that the type and composition of the rubber are critical factors in the design of this type of bearing.

The foundation for the central pier, *Fig.* 6, was arranged to clear the existing signal rod trench as far as possible. To achieve this the central group of 18 piles was positioned 5 ft. 6 ins. off centre, and the end group of eight piles was located parallel to the signal rod trench. The central pier foundations were designed to carry the vertical loads from the two main spans together with the horizontal wind and braking forces and the resulting overturning movement. The latter was achieved by the spread of the large group of 18 piles.

A complete trial erection of the steelwork was made at the contractor's works and the steel subsequently brought by road to the site. The longest piece transported was 95 ft. long. The whole of the erection was carried out by a 30 ton mobile crane without the use of any temporary supports, and without a hitch, in eight days during rail possessions between 11.00 p.m. and 5.00 a.m.



℄ BRIDGE
8'-9"
24'-0"
4'-0"
24'-0"
8'-9"
8'-0" CRS.
CROSS FALL 1 IN 40
RUBBER BEARINGS.
3'0"
SITE JOINT
SITE JOINT
SITE JOINT
SITE JOINT
16'-0 1/64" SUPPORT 16
17'-0 1/4" SUPPORT 14
3'-0"
SECTION A-A
16'-0"
24'-0"
16'-0"

Fig. 5.

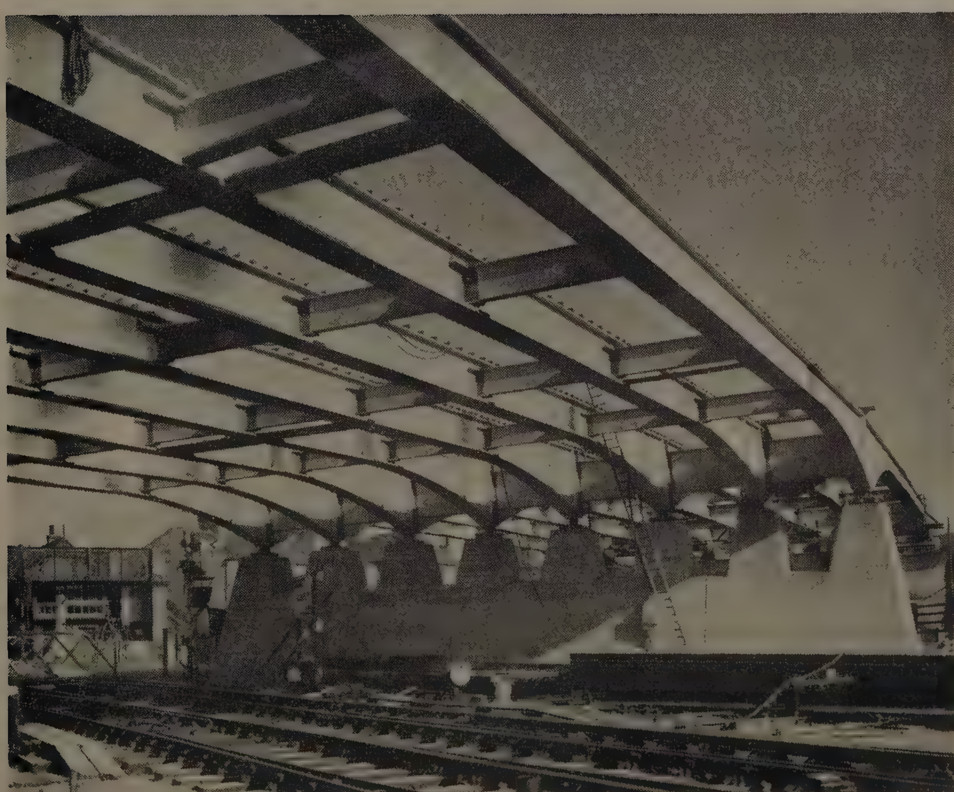


Fig. 6.

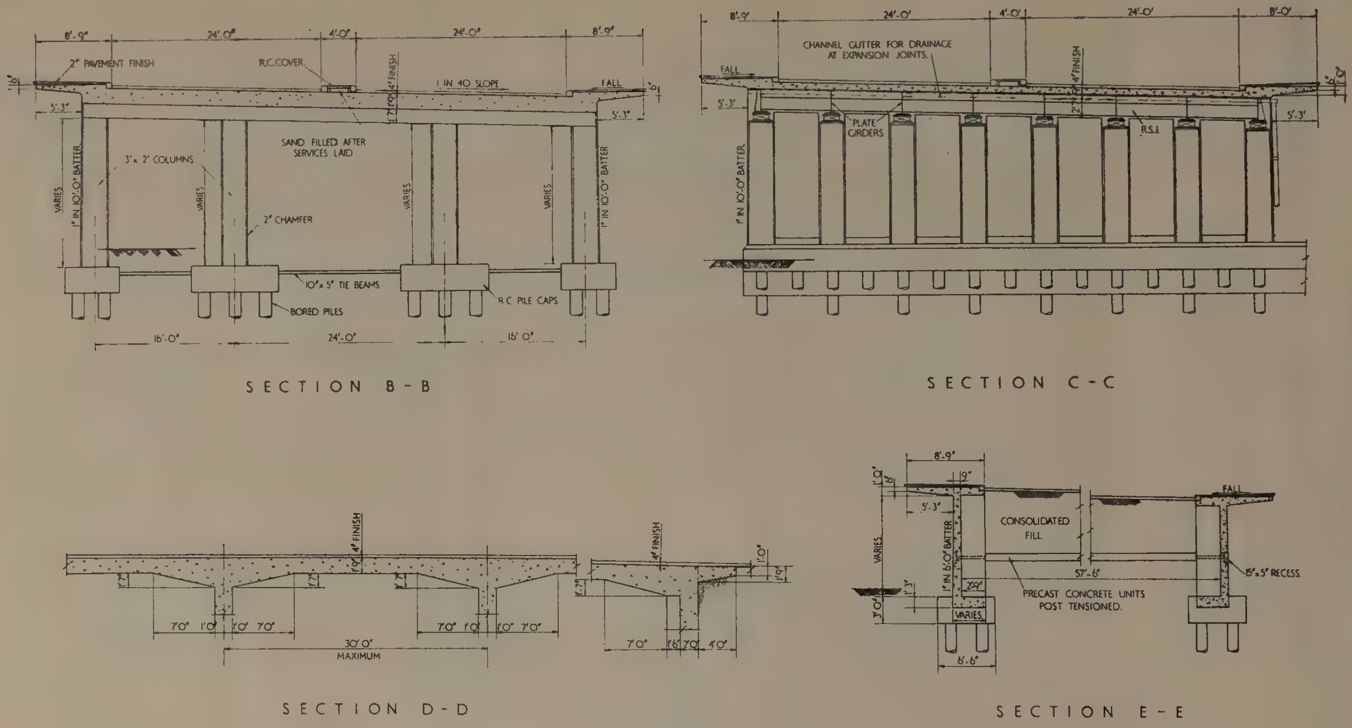


Fig. 7.

(b) R.C. Approach Spans

The spacing of the cross frames in the approach spans was selected from considerations of economy and is approximately 30 ft. as shown in *Fig.* 7.

The total length of the southern approach spans is 360 ft. and the total expansion or contraction from a mean position for a temperature difference of 30°F. would be $\frac{3}{4}$ in. If the spans were to be fixed at the lower and stiffer end, the total movements of both the approach and the railway spans over the latter's abutment would be over 2 ins. Whilst this movement could be taken up by a saw tooth slot type of expansion joint, it was advantageous to split up the total movement and use straight gap expansion joints at more frequent intervals. This was achieved by placing the gaps over lines of supports consisting of double columns of the same total width as the remainder, but separated from each other by a compressible board. The total lengths of the approach spaces on each side of the railway were thus split into shorter sections, and a fixed point provided in each section. The cross frames providing the intermediate points of fixity are designed with the two centre columns fixed at the pile cap and at the deck slab level, and the two outside columns pinned at the top and bottom.

The various parts of the structure which provide the points of fixity are also designed to resist the longitudinal braking and the wind forces. The column details are illustrated in *Fig.* 8—the "pinned" end conditions being achieved by the crossed reinforcement and the reduced effective concrete width. The slot is filled with mastic and the crossed reinforcement is tied to prevent bursting of the core at the change in direction, by mild steel straps with welded in ties. The bars are also welded to the straps and so form rigid prefabricated cages of reinforcement.

(c) Deck Slab and Cross Frames

The typical sections through the deck slab of the approach spans are shown in *Fig.* 7, Sections B-B and

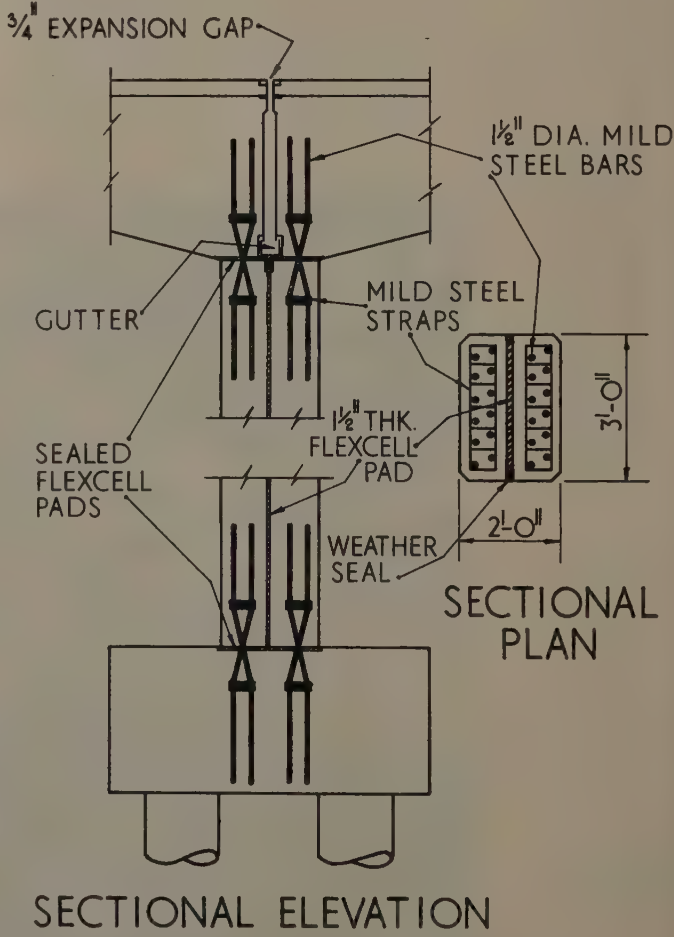


Fig. 8.—Detail of Hinged Concrete Column

Fig. 9.

D-D. The haunching is constant and the variation in the deck slab span, due to the columns being set out radially to the horizontal curve, is taken up in the 21 in. slab section.

The edge stiffness sufficient to support a 5 ft. width of loaded slab, required by the Ministry of Transport regulations, is catered for by extra longitudinal reinforcement provided along the outside 2 ft. width of slab and by the additional strength afforded by the walkway section.

The framing at the top of the columns is provided within the haunching of the slab and the cross fall of 1 in 40 across the carriageways and central reservation is provided by sloping the entire concrete deck—thus providing a uniform thickness of road surfacing and kerb heights. The walkways, however, are level and the cross fall towards the roadway was formed in laying the paving slabs.

The deck shape at the expansion joints is shown in *Fig.* 8; the inclusion of the gutter was necessitated because the intended use of the space beneath the bridge would not permit any flow of surface water through the joint.

(*d*) *Walkway Cantilevers*

The structural slab forming the cantilever walkways was cast level and the cross fall of $\frac{3}{4}$ in. towards the carriageway was formed in the laying of the concrete paving slabs. The cantilever, 6 ins. and 12 ins. deep at the free and fixed edges, respectively, was designed to support a 4 ton wheel load. The outside edges form a continuous line linking the 3 types of structure and are emphasised by the use of white cement in the concrete mix.

The handrails are largely of M.S. tubular construction metal sprayed with aluminium and temperature movements are accommodated by the use of internal sleeves within the top rail.

(*e*) *Staircases*

The pedestrian access on either side of the railway from the existing road levels to the bridge walkways is provided by stairs on the inside of the curve. These stairs landed on to the approach spans and were cantilevered from the columns with a single central spine beam. The stair treads were cantilevered on either side of the beam and faced with precast treads and risers, as shown on *Fig.* 9. Four other stairways were situated at the ends of the approaches and formed the return walls for the embankment slopes at the junction with the retaining walls.

(*f*) *Embankments*

The R.C. retaining walls are tied together by post-tensioned beams as shown in *Fig.* 7 Section E-E. The walls are carried on piles arranged in two rows under each wall, but the pile loading is that due to vertical loads only. The active earth pressure is resisted by the ties which are positioned at the centroid of the horizontal loading diagram.

Whilst the overturning moment on the base of the wall is largely eliminated in the completed structure by means of the tie beams, the walls were designed to resist the moment due to the active pressure of the fill below tie beam level and the consolidation equipment. This moment is resisted by the pile reactions and the torsional strength of the retaining wall section cast at that stage.

The tie beams were post-tensioned by the Gifford-Udall-CCL system and the number of 0.276 in. dia. wires varies with the horizontal force exerted by the different depths of fill at each tie.

The quantity of fill required for embankments to the approaches was imported from local sources. The material obtainable was a well proportioned overburden of stone and clay which was laid in 6 in. layers and consolidated by a 10 ton roller. The wedge

of fill against the wall was consolidated by jumping jack plant with an 8 in. diameter plate.

(g) Sincil Dyke

The approach to the north end of the bridge is crossed by the Sincil Dyke, which forms a part of the drainage system of the Lincolnshire River Board. This Dyke had to be bridged for the Pelham Bridge approaches and also to provide access for Messrs. Ruston and Hornsby's works—since the existing access road was blocked by the approaches on fill.

The Lincolnshire River Board anticipated their improvements scheme programme by authorising work on a total length of some 450 ft. of the Dyke from the New Rustons bridge to the existing culvert at Oxford Street. The channel required in order to cope with future needs was 35 ft. wide × 13 ft. deep. The type of channel to be provided was specified by the River Board as smooth sided, and local planning and utility of space finally decreed that it should be a covered channel throughout.

Two lengths of the culvert forming the bridges for road transport are supported on bored in situ piles which are founded on the clay. This support was provided as an insurance against future movement of the fine sand which is approximately 25 ft. thick between the bottom of the culvert and the clay.

Wall reinforcement was grouped into the ribs formed by the sheet piling and the lengths of the culvert are designed to carry the Ministry of Transport loading on the top deck. The existing Victory Bridge was demolished in two halves to maintain the services carried pending their replacement on the new bridge.

The Victory and Ruston's bridges formed part of the Pelham Bridge contract, but the remainder of the culvert was executed by the same Civil Engineering Contractor under a separate contract with the Lincolnshire River Board.

Drainage and Services

The main stormwater drainage is divided by the

Fig. 10.

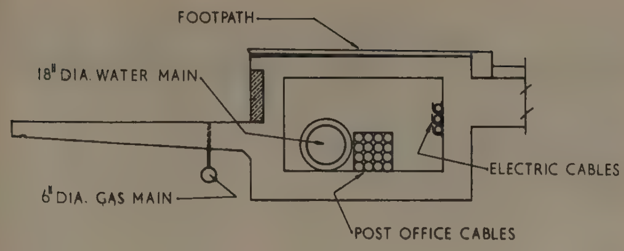
railway and is taken into the Sincil Dyke to the north and into existing drainage to the south. The bridge deck is drained by the cross fall and providing side inlet gulleys along the inside curb of each carriageway, and additional deck drainage is provided at the expansion joints as already described.

The only service carried along the entire length of the bridge was the electricity necessary for the lighting standards along the central reservation. The cable leads into the lamp standards which are set in pockets formed in the concrete slab, or are fixed to special base plates on the 9 in. slab over the railway spans.

Other services along Pelham Street and Canwick Road remained as existing as far as possible, but had to be replaced over the Sincil Dyke. The old Victoria

Site investigation reports showed that the depth of sand and gravel overlying the grey clay on either side of the Dyke was deeper than generally encountered and that the soil consisted mainly of a very fine sand with some silt. Further tests in the banks of the existing channel confirmed that dewatering this strata would not be practical by pumping from sumps, but a well point test proved to be satisfactory.

The construction adopted, shown in *Fig.* 10, utilised steel sheet piling, 20 ft. long, flanked with a dewatering system. The sheet piling forms permanent steel shuttering for the walls and retained the ground outside the channel with a minimum of internal propping during the excavation and construction period.



SECTION THROUGH SERVICES DUCT

Fig. 11

Bridge housed services for electricity power mains, gas mains, high pressure water mains, and Post Office telephones. These are now carried in the services duct shown on *Fig.* 11. The gas mains are slung separately under the dyke slab away from the electricity mains, the remaining services being carried inside the duct. Additional access was provided to the duct in order to facilitate the installation of the 18 in. diameter water mains. This was made by using precast covers for three areas of the pavement slab.

Construction

Some remarks on this subject have already been made and there is little more to add as the construction proceeded according to plan. The only exception was the adoption of the well point method of dewatering for the construction adjacent to the Sincil Dyke—which was not envisaged at the outset.

A general programme was prepared and worked to by and large, though a number of departures have had to be made because the demolitions could not follow a prearranged programme. The partially obstructed nature of the site likewise considerably complicated the setting out—already sufficiently difficult because of the curved nature of the bridge. The only point physically located was the intersection of the centre line of the bridge with that of the central pier, and the fact that the steelwork—erected after the approach spans—fitted exactly into the gap is greatly to the credit of both the main contractors and also the Resident Engineer and his staff.

Ultrasonic Testing

Butt welds made in the shop and on the site were ultrasonically tested by a battery operated set. In all cases the welds were satisfactory.

Piling Tests

Two piles were tested to 50% overload by the direct application of kentledge. The maximum deflections were $\frac{3}{16}$ in. and $\frac{1}{4}$ in., recovering upon removal of load to $\frac{1}{16}$ in. and $\frac{1}{16}$ in.

Costs

At the time of writing, the final account is not yet complete, but there is no doubt that the cost of the work is within the estimate. It is hoped that accurate figures will be available before the date of the paper and it is intended to give a summary of the costs during the introduction.

Architectural Treatment

The description of the bridge would not be complete without some remarks on the architectural treatment, and the authors are indebted for the following observations to Mr. J. R. Atkinson, F.R.I.B.A., A.A. (DIP.) who was responsible for this work on behalf of Messrs. Robert Atkinson & Partners, the Consulting Architects for the bridge.

The southern approaches to the City of Lincoln present a magnificent view of the heights of the ancient city surmounted by the Cathedral. Having this wonderful backcloth in mind, it was decided from the outset that the bridge must on no account spoil the view or contain any heavy or discordant features which would interfere with the general panorama. Considerable credit for this is due to the Royal Commission of Fine Art and to the City Council.

To accentuate the shape of the curves, it was decided to make the continuous footwalk cantilevers with white cement—thus giving a clean " near white " line for the full length of the bridge. The structure terminates at each end by a flight of fairly heavy looking stone approach steps— included in an attempt to anchor the two ends of the bridge and to give it a springing-off point from the solid stone-faced ramp approaches of the road. The two staircases on each side of the railway are of a completely different type—to fit in with the general nature of the structure.

Some difficulty was experienced in finding footholds for the supporting piers amongst the existing railway tracks, and in discovering some sort of rhythm for these supports. On the railway spans, the supports were varied in design and shape the more to express their importance and purpose. All concrete columns and abutments are cast with exposed coarse ballast aggregate giving weight to the finer and lighter coloured aggregate used on the cantilever walkway strip above.

A mounting for a bronze tablet to record the official opening of the bridge is provided at the end of the north approach and it is intended to remount the original tablet commemorating the construction of the original and now demolished Victoria Bridge by J. Padley Esq.—a former Lincoln City Engineer & Surveyor of no mean repute.

Acknowledgments

There is no doubt that the salient feature of the construction of Pelham Bridge is the quite exceptional co-operation and good fellowship which existed throughout the progress of the work amongst all concerned. The City Council, the Lincolnshire River Board, the Consulting Engineers, the Consulting Architects, the Ministry of Transport (London and Nottingham), the British Railways (London, Doncaster and Lincoln), the Electricity, Gas, Telephones and Water Authorities, and both main Contractors, combined into a team whose sole object was to complete the work as quickly as possible ; and it is this general esprit de corps which will be mostly remembered by the authors in connection with the Pelham Bridge, Lincoln.

Particular mention in this connection must be made of Mr. A. Adlington M.I.C.E., M.I.Mun.E., Lincoln City Engineer & Surveyor in respect of the Pelham Bridge, and of Mr. F. H. Tomes, O.B.E., M.I.C.E., M.I.W.E. Engineer to the Lincolnshire River Board, in respect of the Sincil Dyke culvert.

The authors would also like to render thanks to the Lincoln City Council, the Lincolnshire River Board and W. S. Atkins & Partners, the Consulting Engineers for the bridge and Sincil Dyke culvert, for their kind permission to present this paper.

The photographs for Figs. 9 and 10 have been kindly provided by the Lincoln City Engineer & Surveyor, that for Fig. 1 by Tarmac Limited, and those for Figs. 4 and 6 by the Andre Rubber Co. Ltd. and The Butterley Co. Ltd. respectively.

Arching Action in Reinforced Concrete Slabs*

Written Discussion on the Paper by Professor A. J. Ockleston, B.E., Ph.D., D.Sc.(Eng.), M.I.Struct.E., M.I.C.E.

Mr. A. J. Ashdown (Associate-Member) commented that Professor Ockleston's very interesting paper endeavoured to bridge the gap of the large discrepancy between failing loads calculated on the latest theories for moments of resistance and the actual failing load.

For this case of lateral support, there was certainly an additional resistance, as the model indicated. This additional resistance could only function when the slab was deflected, and the lower edge of the triangular pieces bore upon the rigid lateral support.

The large imposed eccentric force visualised as acting on the concrete slab, by the proposed formula, would surely cause the lateral support to distort both horizontally and vertically, and so to lose much of its supporting value.

Since the slab after bending was considered to act as an arch or dome, the additional compressive force acted throughout the span, and it would suggest that strain measurements on the top and bottom surfaces at the points of contraflexure of a similar test slab would indicate what this compression actually amounted to. Mr. Ashdown felt that the formula produced by Professor Ockleston was not completely valid, since the strains due to arch shortening or the large strains due to bending etc., were not taken into account; so that arch action really accounted for quite a small proportion of the load.

Approaching the problem from another angle, and considering the lengthening of the span due to deflection, by assuming a linear deflection along the short span, we had, along the neutral line assumed at the centre of the thickness of the slab $s^2 = a^2 + \Delta^2$

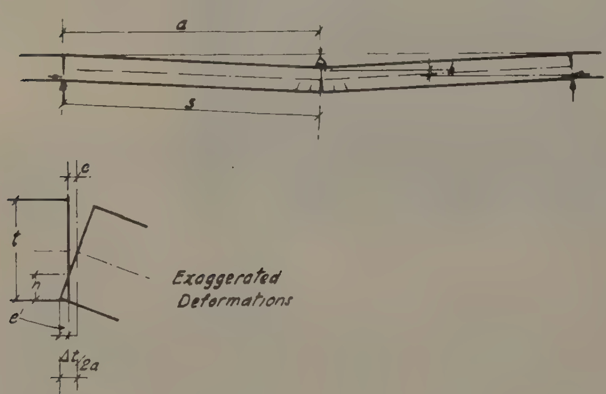


Fig. 1

where s was the extended length, then

$$(s - a)\ (s + a) = \Delta^2,$$

whence the extension of "a" was $s - a = \dfrac{\Delta^2}{2a}$.

The slope at the end would be $\dfrac{\Delta}{a}$, so that the bottom surface rotated through a distance of $\dfrac{\Delta t}{2a}$ from the neutral line. The total extension of the slab was divided between the centre and the two supports. Then the extension at the support

$$e = \frac{2\ (s - a)}{3} = \frac{\Delta^2}{3a}$$

The total deformation at the bottom surface was

$$\frac{\Delta t}{2a} - \frac{\Delta^2}{3a} = e' = \frac{\Delta}{6a}\,(3t - 2\Delta)$$

assumed occurring in a length of $^2/_{3a}$, so that the strain at the bottom surface was $\Delta\ (3t - 2\Delta)/4a^2$, which, for this span amounted to

$$\frac{2.58\ (3 \times 5.25 - 2.58)}{4 \times 81^2} = 0.0013$$

The initial E_c for this concrete was about 4×10^6 lb/sq. in., but owing to creep and plasticity which had occurred due to bending moment stress, the secant modulus E'_c was only about 1×10^6, so that the actual stress at the soffit due to arch action was about 1,300 lb/sq. in.

The position of zero stress was situated at

$$n = \frac{t}{2} - \frac{\Delta}{3} = 1.765 \text{ ins.},$$

then the compressive force

$$= c = \frac{1300 \times 1.765}{2} \times 12 = 13{,}750 \text{ lb/ft.run.}$$

Assuming the C.G. $= \gamma = 0.4n$, then the arch rise $h = t - \Delta - 0.8n = 1.26$ ins. at the centre length only.

Assuming a parabolic arch line against uniform loading

$$c = \frac{wl^2}{8h} \text{ whence } w = \frac{8 \times 1.26 \times 13750}{12 \times 13.5^2} = 64 \text{ lb/sq.ft.}$$

On the long span the strain was 0.00092, and the stress = 920 lb/sq. in. c = 9850 lb/ft. run whence w = 32 lb/sq. ft. A total of 96 lb/sq. ft. Away from the centre lines of the slab, the rise h of the arch increased but the direction of arching changed towards the shorter diagonal span and it would be difficult to estimate this effect.

Incidentally, the width of the crack at the support was $\dfrac{\Delta}{6a}\,(3t + 2\Delta)$, which amounted to 0.0975 in., compared with a measured width of 0.1 in.

It would be noted that c has been calculated on an assumed linear distribution of stress, whereas a parabolic distribution is nearer the truth; this would have the effect of increasing the arching effect by 33%.

Reply to Mr. Ashdown

The Author thanked Mr. Ashdown for his comments and agreed that the horizontal forces which must be developed if an appreciable load was to be carried by arching action would be large, and that to develop

* *Published in "The Structural Engineer," Vol. XXXVI, No. 6, pp. 197-201 (June, 1958.)*

such forces there must be adequate lateral restraint at the edges of the loaded panel. In the case of the Old Dental Hospital tests the necessary restraint was provided by the unloaded panels which completely surrounded the test slabs. The minimum restraint was at one of the long edges of the test panels, which was parallel to and about 8 ft. from the edge of the floor system. For horizontal loads the side panel along this edge formed a deep girder of channel section (the slab acting as the web and the beam ribs as the flanges) with a span : depth ratio of approximately 2. It was estimated that the maximum horizontal deflection of this deep girder due to the membrane forces would be less than 0.01 in. The other three sides of the test panels were farther from the sides of the floor system and the lateral restraint at these edges was considerably greater.

Vertical deflection at the edges of the loaded panel would not, in itself, affect arching action—what would matter would be the deflection of the slab relative to the supports. The horizontal reactions due to arching would have no significant effect on the vertical deflections since they would not affect the total vertical load on the supports, though they might modify its distribution somewhat.

Mr. Ashdown was incorrect in stating that in the analysis of arching action in the test slabs the Author had neglected the strains due to arch-shortening and bending. The expression for the load carried by arching action had been obtained in terms of the deflection of the slab relative to the supports, and when it was applied to the test slabs the experimentally determined deflection used. This deflection would depend upon both the membrane forces and the bending moments, and also upon any horizontal movements of the panels surrounding the test slab, and consequently all these effects had been fully taken into account.

The analysis which had been given by Mr. Ashdown did not really deal with arching action. In the initial step, when the effects of bending only were considered, it had been assumed that the neutral axis was at the centre of the thickness of the slab, and that in consequence the neutral surface was extended as the slab deflected. The conditions assumed corresponded to those for a homogeneous or uncracked slab, and the case dealt with by Mr. Ashdown was that of tensile membrane or catenary action, and not arching action. For arching action to occur it was essential that, for bending alone, the neutral axis or centre of rotation at the supports should be below that at the centre, so that the neutral surface was domed upward and became compressed as the slab deflected downward. This would be the condition in a cracked reinforced concrete slab if the deflections were small.

Even for the case which he had in reality considered Mr. Ashdown's analysis was incorrect, as was evident from the fact that he had assumed the neutral surface to be extended and yet his analysis showed the resulting membrane forces to be compressive. In estimating the mean strain along the lower surface he had considered the compressive deformation at the support but had neglected the tensile deformation at the centre, tacitly assuming cracking which was inconsistent with his initial assumption. In his estimate of the membrane forces he had again neglected the tensile stresses and moreover had assumed the compressive stresses to be due to arching alone, whereas they were in fact the result of bending combined with tensile membrane action.

Professor R. G. Robertson (Member), Mr. A. C. Liebenberg (Associate-Member) and Mr. D. J. McGaw congratulated Professor Ockleston on his paper, which they had found of special interest as they had suggested arching action ever since the publication[1] of the Old Dental Hospital test results on a two-way spanning slab. A similar result was obtained in the tests on the Stairway flights of the Old Dental Hospital Building and as reported[2] this was attributed to arching but Professor Ockleston did not agree at that time that arching also occurred in the floors.

In the stairs the intermediate landing supporting the lower flight deflected downwards initially, but after the flight had developed cracks it thereafter deflected upwards, which left no doubt that the exceptional load (three times in excess of that estimated) was obtained by the mechanism of arching.

Professor Ockleston had introduced the subject in a very clear manner and it was to be hoped that more research workers would show interest in this phenomenon. Apart from references to arching in beams which dated back to the birth of reinforced concrete, no published information on the phenomenon of arching (or dome action) in slabs could be traced with the exception of recent references[3,4] to the subject in connection with prestressed concrete bridges and runways for airports.

The writers were undertaking research at the University of Cape Town and full scale tests to destruction on 49 slab panels of Alliance House, a reinforced concrete building in Cape Town, had already been carried out, with the co-operation of the Director N.B.R.I., C.S.I.R., prior to its demolition in December 1957. Only two sizes of slabs could be tested, but these had various degrees of restraint against horizontal deflection at the perimeters, so that the tests provided an excellent opportunity to investigate arching action and these were the first known tests in which the expansion of the slabs was recorded.

The slabs were lightly reinforced with no top steel over the supports but nevertheless they resisted very large loads which could only be accounted for by the phenomenon of arching. They hoped to present a paper in the near future describing the results and the conclusions which could be drawn from such a large number of tests. These tests were being followed up by laboratory work to determine certain basic relationships necessary for completion of this research for a higher degree thesis.

The assumptions made by Prof. Ockleston were only sufficiently accurate for a very approximate determination of the upper limit of the load that could be carried by arching action before crushing failure of the slab. The formula derived for w the load could also be obtained by a simple consideration of the equilibrium of the slab portions. Apart from referring to effective horizontal restraint at the supports, he had not allowed for the effect of horizontal deflections at the supports and the " rib-shortening " effect in the slab portions which influenced and might control the ultimate load.

There were three possible modes of failure of the arching action, viz.

(1) Compression failure of concrete.

(2) Excessive deflection due to horizontal spreading at the supports combined with " rib-shortening."

(3) Shear failure.

The first mode of failure was likely in heavily reinforced concrete slabs with some horizontal restraint in addition. The second was the cause of failure in all

the panels tested in Alliance House with the exception of a few subjected to point loads near one end which failed by the third mode in shear.

It was not clear why Professor Ockleston should state that "arching action is most likely to develop in lightly reinforced slabs." It might be more correct to say that at the ultimate load the ratio of the load carried by arching to the load calculated by previous theories would be greater for lightly reinforced slabs, but this was self-evident.

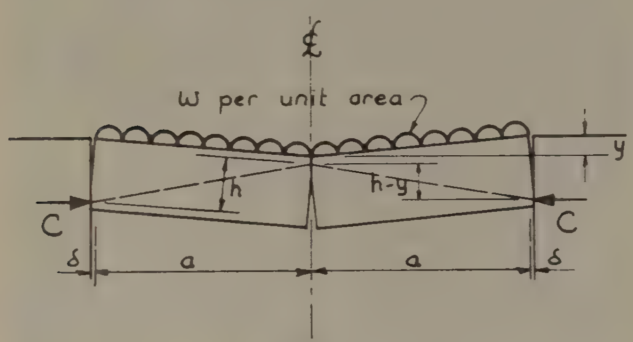


Fig. 2

Referring to Fig. 2, the writers stated that using Prof. Ockleston's notation and neglecting any change in length of the base (a) it was evident that for a slab on two supports the unrestrained horizontal expansion on each side of the centre line was

$$\int_0^{\Delta} \frac{h-y}{a}\, dy = \frac{\Delta}{a}\left(h - \frac{\Delta}{2}\right)$$

therefore

$$C = k\,\frac{\Delta}{a}\left(h - \frac{\Delta}{2}\right)$$

where k = Force per unit width of slab generated by unit expansion on each side of the c/l crack.

By taking moments about the abutment hinge the distributed load (w) per unit area

$$= \frac{2C(h - \Delta)}{a^2}$$

$$= 2k\,\frac{\Delta}{a^3}\left(h - \frac{\Delta}{2}\right)(h - \Delta)$$

Now (w) was a maximum when $\dfrac{dw}{d\Delta} = 0$

i.e. $(h - \Delta)\,(h - \Delta) - \Delta\left(h - \dfrac{\Delta}{2}\right) = 0$

i.e. $\Delta^2 - 2\,\Delta h + \dfrac{2}{3}\,h^2 = 0$

i.e. $\Delta = \left(1 - \sqrt{1 - \dfrac{2}{3}}\right) h = 0.42h$

and $(w)_{\text{ult.}} = 0.38k\left(\dfrac{h}{a}\right)^3$

This ultimate load depended on the resistance to expansion and not on the compression strength of the concrete.

Taking (T) to be the total tensile yield resistance of the slab reinforcing in the top over the supports added to that in the bottom at midspan per unit length, then the addition due to slab reinforcing was

$$w_r = 2\,\frac{Th}{a2} \text{ approximately}$$

Therefore the total ultimate load

$$w = 2\,\frac{h}{a}\left(\frac{T}{a} + 0.19k\,\frac{h^2}{a^2}\right)$$

The critical deflection ($\Delta_{cr} = 0.42h$) was the deflection at which the maximum load carried by arching was attained and was confirmed by the results of the tests on the slabs of Alliance House which were lightly reinforced and in most cases did not show any sign of crushing failure.

It would be noted that the transverse deflection relative to the beams reported by Prof. Ockleston was about 2 inches. If we assumed $h = 4.8$ ins. in his slab, allowing $\frac{1}{2}$ in. for stress blocks, then $\Delta_{cr} = 2.0$ ins. which also confirmed the above equation.

The determination of the modulus of horizontal restraint (k) was essential in order to be able to predict the ultimate load in case of failure by mode (2). The problem was highly complex but by a theoretical analysis combined with test results they hoped to establish rules for incorporating arching effects into design practice. Bearing in mind the considerable increase in ultimate resistance due to arching, such rules need not be very precise.

No method of design resulting in visible cracks appearing under working loads could be justified in practice, but for slabs complying with the conditions necessary for arching to occur, the factor of safety as determined by conventional methods could be reduced considerably, the object being to ensure no cracking, but working to closer limits as total collapse would be ruled out.

Obviously such methods could only apply to slabs where large deflections were not serious. It should have special significance in structures like magazines for explosives, air raid shelters and other defence works where only the ultimate resistance really mattered.

Reply to Professor Robertson, Mr. Liebenberg and Mr. McGaw

The Author was pleased to learn some details of the loading tests on slabs which had been carried out at Cape Town and looked forward with interest to the full reports on these tests.

He regretted that a statement he had made in a letter to Mr. Liebenberg appeared to have been misunderstood. As was clear from the discussion on his original paper on the Old Dental Hospital tests he had for a long time felt that something in the nature of arching might well be the reason for the unexpected strength shown by the tests on the two-way slabs, but it was not until a year or so ago that he had developed an analysis which appeared to give a reasonable explanation and was consistent with the observed behaviour of the slabs.

With regard to the comment that no allowance had been made in his analysis for the effects of rib-shortening or horizontal displacements at the supports he could only reiterate what he had said in reply to Mr. Ashdown. By using in his calculations the experimentally determined deflections, which depended upon bending, rib-shortening and horizontal displacement at the supports, he had taken all of these effects fully into account.

He thought that the reason why arching action was most likely in lightly-reinforced slabs should be obvious. Arching action could occur only if the neutral surface of the slab was arched upward so that downward

deflections would give rise to compressive membrane stresses. In a lightly-reinforced slab the neutral axis, after cracking, would be close to the compression surface and the arching of the neutral surface would be most marked. In a heavily-reinforced slab on the other hand the neutral axis, after cracking, would be fairly close to the centre of depth of the slab and the neutral surface would be less arched. A given vertical deflection would therefore cause less spread at the supports than for a lightly-reinforced slab. For this reason, and because of the smaller rise of the neutral surface, very considerable lateral rigidity at the supports, and not merely " some horizontal restraint," would be necessary if arching action was to be important. Moreover, because of the flatter neutral surface, a relatively small deflection would be sufficient to destroy all arching action in a heavily reinforced slab spanning in one direction, and there was therefore much more likelihood of such a slab failing as a result of bending, possibly combined with tensile membrane or catenary action, than would be the case for a lightly-reinforced slab.

The Author had limited his paper to the presentation of a theory which appeared to explain the behaviour of the two-way slabs which had been tested. For other cases, such as that of a two-way slab where the deflection was such that catenary action occurred at the centre while arching action was taking place across the yield lines at the corners, the theory would require modification.

The analysis given by Professor Robertson, Mr. Liebenberg and Mr. McGaw dealt with yet another case, that of a slab spanning in one direction which failed as a result of instability. From the assumptions tacitly made and from the statement that the ultimate load did not depend upon the compressive strength of the concrete it was clear that purely elastic behaviour had been assumed, although the subsequent reference in the discussion to " stress blocks " suggested that this basic limitation had on occasion been overlooked. It should perhaps also be emphasized that the " modulus of horizontal restraint," k, was a function not only of the restraint provided by the supports but also of the properties of the slab itself.

In the Author's analysis h represented the distance between the resultant membrane forces for one particular condition, that is, at failure. In the Robertson-Liebenberg-McGaw analysis h represented the distance between the resultant membrane forces for all values of the deflection. Since h must decrease as the slab deflected and arching forces were developed it must be a function of y or Δ. It had however been treated as a constant, and consequently the expressions obtained for the critical deflection and the ultimate load could only be approximate.

The analysis put forward in the discussion had been based on the assumption of elastic behaviour, and this would limit its range of validity. The expression given for the unrestrained horizontal spread at each support was $\frac{\Delta}{a}\left(h - \frac{\Delta}{2}\right)$ so that if spread were completely prevented the average strain along the line of action of the membrane forces would be

$$\frac{\Delta}{a^2}\left(h - \frac{\Delta}{2}\right)$$

For the critical deflection $\Delta = 0.42\,h$ this mean strain would become $0.33\left(\frac{h}{a}\right)^2$

The value of h/a for a slab of normal proportions would be something like $\frac{1}{15}$ and for such a slab the average compressive strain due to membrane forces if spread were completely prevented would be about 0.15 per cent. At the cracked sections at the centre and the supports where the membrane forces are applied over only a part of the cross-sectional area the maximum strains, which will be further increased by the effects of bending, must be considerably greater than the average strain.

Concrete developed its maximum stress at a strain of about 0.2 per cent and ceased to be approximately elastic at a considerably smaller strain, 0.05 per cent or thereabouts. It was therefore evident that unless the compressive strains were relieved by appreciable lateral movement at the supports, and the arching action thereby correspondingly reduced, the concrete would cease to behave elastically well before the critical deflection was attained, and the formulae given for critical deflection and ultimate load would no longer be even approximately valid.

Similar calculations applied to the Old Dental Hospital slabs indicated that for both the short-span and the long-span directions the maximum strains would be considerably beyond the elastic range, and crushing of the concrete on the underside of the slab was in fact observed during the tests, at all the supports. For this reason, and because the formula for critical deflection was derived for a slab spanning in one direction, the Author thought that the agreement between the observed deflection at failure and the calculated critical deflection was more of a coincidence than a verification of the analysis put forward in the discussion.

References

1 Ockleston, A. J., " Load Tests on a Three Storey Reinforced Concrete Building in Johannesburg." *The Structural Engineer*, Oct. 1955, p. 304.

2 Liebenberg, A. C., " Load Tests on Stairways of a Reinforced Concrete Building in Johannesburg." Paper No. 4. *The Concrete Association of South Africa*, November 1956, p. 22.

3 Freyssinet, E., "Importance et difficultés de la mécanique des bétons " presented at the Congrès du Béton Précontraint at Ghent in September 1951.

4 Guyon, Y., " Moment distribution in Statically Indeterminate Prestressed Structures beyond the Elastic Phase " presented at the Second Congress of the Federation Internationale de la Précontrainte at Amsterdam in 1955.

Institution Notices and Proceedings

GENERAL MEETING

A General Meeting of The Institution of Structural Engineers was held on Thursday, 2nd October, 1958, at 6 p.m., when the Presidential Address for the Session 1958-1959 was given by Mr. G. S. McDonald, M.I.Struct.E., M.I.C.E., M.I.Mun.E.

Professor Sir Alfred Pugsley, O.B.E., D.Sc.(Eng.), F.R.S., M.I.Struct.E., M.I.C.E., F.R.Ae.S., the retiring President, occupied the Chair.

After welcoming the many guests who were present at the meeting, the retiring President presented the following Institution awards gained during his year of office :

The Institution Branch Award for the best paper from amongst those for which Branch Prizes have been awarded, to Mr. C. E. Saunders, whose paper entitled " Some Structures Involving Unusual Design Problems " was read before the Western Counties Branch.

The Institution Bronze Sessional Medal for the best paper read before the Institution or the Branches during the Session, to Mr. G. B. Godfrey, for his paper " Post-War Developments in German Steel Bridges and Structures ".

The Chairman, before installing his successor, said it had become customary for the retiring President to say a few words, and he would avail himself of that privilege.

First, of course, he wanted to express his thanks for all the help he had received during the past session from members of the Institution and of the staff. He had realised the very generous and able support that was available to any President and which he was sure would be accorded to his successor. He had learnt how the notable liveliness of the Institution, which he had always appreciated and which had always impressed him, depended not on the President, but on the many able members, particularly Members of the Council, who devote their time and abilities to the Institution ; he assured them that, as President, he was particularly grateful.

Also, Sir Alfred said, he had appreciated more than ever the invaluable services of the Institution's Secretary and his staff. The past year had been particularly difficult for them. It had started with improvements and decorations to the Headquarters building, which had made life very uncomfortable, and had ended with the problems arising out of the preparations for the Jubilee celebrations. Therefore, he expressed special thanks to them.

Speaking of his visits to the Branches, Sir Alfred said how much he had enjoyed and valued the various Chairmen's addresses he had heard throughout the country. He had also found himself studying the habits and customs of Lord Mayors and other civic dignitaries, and had been unexpectedly impressed by the very real interest which Lord Mayors and Mayors throughout the country had shown in the affairs of the Institution. It might be that post-war reconstruction work had been prominent in their civic lives ; but their interest was pleasant to find and augured well for our future public relations.

He had also found himself studying the annual dinners and other functions of other Institutions. Not only had he enjoyed them, but also had felt that the functions of The Institution of Structural Engineers bore comparison with the best.

One aspect of his year of office was that he happened to be a President who lived more than a hundred miles from London. That he had been elected in such circumstances was to him a particular honour ; but he had realized that the Institution had run more than the usual risk, he might almost say a structural risk ! He felt sure that it was only by the special efforts made by Members of Council, such as the Vice-Presidents, and by the members of the staff that the risk had been taken successfully ; for without those efforts such a structure could have collapsed. For that he was very appreciative indeed.

With those thoughts in mind, and, he was sure, with much less risk, Sir Alfred presented Mr. McDonald as President of the Institution, and remarked that he too lived a good distance from London. He came to office with a fine record of service to the Institution, both in London and in the Branches ; he came with the practical skill and the lively common sense of the best of the Birmingham engineers, and with great experience of Birmingham engineering. He came too with all the vigour and good humour of the North, and of both characteristics his friends were well aware he would need much in this year of Jubilee celebrations. For his good humour and practical wisdom, all who had worked with him in recent years had come to value him as a colleague and looked forward to his leadership.

With great pleasure Sir Alfred invested Mr. McDonald with the Presidential Badge of office, and assured him that he had the best wishes and the confidence of all.

The President then formally occupied the Chair, amid prolonged applause.

Mr. F. R. Bullen, B.Sc.(Eng.), M.I.Struct.E., (Vice-President) said it fell to him to perform the very pleasant duty to propose a vote of thanks to Sir Alfred Pugsley on behalf of the Institution for all the hard work he had put in during his year of office. It seemed to Mr. Bullen that the office of President became more and more responsible as the years passed and called for a great deal more self-sacrifice.

Looking back over the past year, what did they see in their President ? They saw a charming personality, an unusually modest man, a man of considerable poise ; that was an appropriate term for a structural engineer. Under the Presidency of Sir Alfred, with his cool confidence and competence, they knew they had in charge of their meetings someone who knew exactly what he ought to do and exactly which way he ought to lead.

As evidence of his interest in and readiness to work for the Institution, he was to broadcast on October 15th. Mr. Bullen commended that occasion to engineers, for Sir Alfred would speak not only on behalf of engineering in general, but particularly of the Institution. If anybody could cram more thought into a few words than could Sir Alfred, then one had yet to meet him.

With the very greatest pleasure, Mr. Bullen expressed to Sir Alfred the Institution's appreciation of all his hard work on its behalf during the past year.

Dr. D. D. Matthews, M.I.Struct.E., M.I.C.E., (Chairman, Lancashire and Cheshire Branch) seconded the vote of thanks.

In the absence of a British Standard for Presidents of engineering institutions he thought it was sufficient to assess the work of a Presidential year by the extent to which the office was enhanced by the holder. The Institution was indeed fortunate in the honour Sir Alfred had paid it in this respect. The members had been privileged to witness a combination of wisdom and humanity in Sir Alfred's conduct of the Institution's affairs with a shrewd and really engaging modesty.

It was indeed a great pleasure to second the vote of thanks to him.

(The vote of thanks was accorded with acclamation).

Sir Alfred Pugsley briefly expressed his thanks for the over-generous way in which the remarks had been made and received.

Sir Alfred Pugsley then resumed the Chair and invited Mr. McDonald to present his Presidential Address, which is published in this issue.

Mr. L. E. Kent, B.Sc.(Eng.), M.I.Struct.E., M.I.C.E., (Vice-President) proposed a vote of thanks to Mr. McDonald for the Presidential Address. This was seconded by Lt.-Colonel G. W. Kirkland, M.B.E., M.I.Struct.E., M.I.C.E., (Vice-President) and was heartily accorded by the meeting.

The President, responding and thanking Mr. Kent and Colonel Kirkland for their kind remarks, said he was very impressed that so many of his friends had come to the meeting to hear his Address, and he was grateful to all present for having done so. The occasion had given him a great deal of encouragement to go ahead during the next year.

ORDINARY GENERAL MEETING

An Ordinary General Meeting of the Institution of Structural Engineers was held at 11, Upper Belgrave Street, London, S.W.1., on Thursday, 23rd October, 1958, at 5.55 p.m., Mr. G. S. McDonald, M.I.Struct.E., M.I.C.E., M.I.Mun.E., (President) in the Chair.

The Minutes of the Ordinary General Meetings held on the 22nd May and 26th June, 1958, as published in the Journal, were taken as read, were confirmed and signed.

The following members were elected in accordance with the Bye-Laws. Will members kindly note that the elections, as tabulated below, should be referred to when consulting the Year Book for evidence of membership.

Graduates

Burnett-Stuart, Thomas, of Huntly, Aberdeenshire.
Dugdill, Bernard Vincent, of Wigan, Lancashire.
Edlington, Jack, of Brigg, Lincolnshire.
Ferrelly, John Noel, of Kingston-upon-Thames, Surrey.
Kalra, Jagdish Chander, of London.
Krishnarao, Raghupatruni, of Andhra Pradesh, India.
Mannavarayan, Sebamalai Loyolla, of London.
Macfarlane, John, of Port Elizabeth, South Africa.
Mortimer, Cyril Paley, of London.
Murphy, Brian Christopher, of Liverpool.
Olaofe, Josephus Folawiyo, of London.
Patel, Kantilal Varadhbhai, of Bristol.
Reeve, Colin William, of Salisbury, Southern Rhodesia.
Roy, Mihir Kumar, B.Sc.Calcutta, of London.
Sandhu, Iqbal Singh, of London.
Shah, Chandrakant Bhailal, of Ahmedabad, Bombay State, India.
Smith, Stanley, of Cape Town, South Africa.
Tambe, Madhav Shrirang, of Bombay, India.
Tulapurkar, Chandrashekhar Bhalchandra, of Indore, India.

Associate-Members

Adamson, Eric, M.Eng., A.M.I.C.E., of Singapore.
Appleton, Eric Walter, of Gt. Bookham, Surrey.
Campbell, Charles, of Durban, Natal, South Africa.
Corns, Samuel Maurice, B.Sc.(Eng.) London, of London.
Crease, Brinley, B.Sc.(Civil) Cardiff, of Woodley, Berkshire.
Davies, David Oakley Mason, B.Sc. Wales, of Cardiff.
Du Heaume, Peter Learmouth, B.Sc.(Eng.) London, of Bromley, Kent.
Eadie, Douglas McDonald, B.Sc.(Eng.) London, of Harpenden, Hertfordshire.
Ee Hoong Guan, Robert, of Singapore.
Gore, Ashok Narhari, B.E.(Civil) Bombay, of Bombay, India.
Hall, Wilfred Kenneth, B.Sc.(Eng.) London, of Orpington, Kent.
Lister, Kenneth Francis, B.Sc.(Eng.) London, of London.
Loh Teh-Kang, Peter, of Kuala Lumpur, Malaya.
Meakin, James, of Sheffield.
Mowatt, Albert Ernest, B.Sc.(Eng.) Glasgow, of Mabelreign, Southern Rhodesia.
Parker, Frederick John, M.Eng., A.M.I.C.E., of Hong Kong.
Radder, Theodorus Johannes Cornelis, of Johannesburg, South Africa.
Ransome, Charles William, of Montreal, Canada.
Smith, Victor Francis Henry, of Warlingham, Surrey.
Telang, Madhav Subrao, B.E.(Civil) Bombay, of New Delhi, India.
Thorpe, Walter, of New Mills, nr. Stockport, Cheshire.
Tregilgas, William Gerald, D.F.C., of Birkenhead, Cheshire.

Transfers

Students to Graduates

Asu-Eze, Sylvester, of London.
Bayat, Hassan Khaled, of Bradford, Yorkshire.
Bogle, John Brian, of Stockport, Cheshire.
Bonser, Donald Robert Martyn, of Hounslow, Middlesex.
Burrows, Ronald Edward, of Birkenhead, Cheshire.
Cumberlidge, Philip, of Macclesfield, Cheshire.
Dave, Tripurashanker Labhashanker, of Nairobi, Kenya.
Edwards, Alun Jones, of Welshpool, Montgomeryshire.
Ford, Ronald Francis, of Chepstow, Monmouthshire.
Geh Ik Soon, of Singapore.
Howard, Douglas John, of Sidcup, Kent.
Johnstone, Brian Kenneth, of Port Elizabeth, South Africa.
Jones, Roy, of Birmingham.
Kurien, Mohan Zacharia, of Bombay, India.
Martin, Francois Regis, of Bradford, Yorkshire.
Meek, William Charles, of Lower Hutt, New Zealand.
Morton, Howard, of Scunthorpe, Lincolnshire.

PAGE, Colin Frederick, of Bristol.
RANGWALA, Shantilal Chimanlal, of Ahmedabad, India.
ROCHESTER, Terence Anthony, of London.
SADLER, Thomas John, of London.
SEN, Tarunendra, of London.
SIMPSON, Alan Jeffrey, of Scunthorpe, Lincolnshire.
SYMONDS, Raymond Charles William, of Cheltenham, Gloucestershire.
WEBB, Ian Robin, of London.

Student to Associate-Member

McINTOSH, Donald Fraser, of Malacca, Malaya.

Graduates to Associate-Members

BAIRD, Jack Alexander, of Bexleyheath, Kent.
BONE, Eric Walter, of Mitcham, Surrey.
BOTHMA, Kenneth Harold, of Johannesburg, South Africa.
BURTON, Michael Arthur Brian, of Kingston-upon-Thames, Surrey.
CAMIS, Roy Alfred, of Dagenham, Essex.
CHAN HONG-CHING, B.Sc. Hong Kong, of Hong Kong.
CHAN KA YIK, of Sandakan, North Borneo.
COLE, Kenneth Frank, of Horley, Surrey.
COOKE, Donald Lewis, of London.
COOPER, Michael Lloyd, B.Sc.(Civil) Nottingham, of Richmond, Surrey.
COSGRAVE, James, A.R.I.C.S., of London.
DE LOOZE, Eric Norman, of London.
DU TOIT, George Alfred, of Clifton, Cape, South Africa.
ELLIOTT, Percy John, of Cardiff.
ER KIAH CHOON, of Seremban, Malaya.
FAIRHURST, Leonard, B.E.(Civil) Liverpool, of Sunshine, Victoria, Australia.
FLINT, John Michael, of London.
GALLAGHER, David William, of Christchurch, New Zealand.
GARBUTT, Alan Watson, of Middlesbrough, Yorkshire.
GOODFELLOW, Reginald George, of West Byfleet, Surrey.
GROUT, Arthur Wilfred, B.Sc.(Eng.) London, of Sutton Coldfield, Warwickshire.
HAINES, Warwick Clive, of Cardiff.
HARRINGTON, James Joseph, B.E., N.U.I., of Cork, Ireland.
HICKLENTON, Brian Stuart, B.Sc. (Civil) Leeds, of Hull, Yorkshire.
HOBBS, John Jennings, of London.
HOWARTH, George Brian, of Manchester.
JAMIESON, Donald, of Clydebank, Dumbartonshire.
JOHNSON, Roger Paul, M.A. (Cambridge), of London.
KING, Michael Dexter, of Port Elizabeth, South Africa.
KU JEN CHIEH, of Hong Kong.
LAU YAU CHUN, of Hong Kong.
LEADBEATER, Geoffrey, of Knutsford, Cheshire.
McCAUGHEY, John Donald, M.A. (Cambridge), of Helen's Bay, Co. Down.
McDONNELL, Gerald, of London.
McDONNELL, Robert, B.E., N.U.I., of Antigonish, Nova Scotia, New Zealand.
MERCER, Horace John Gerald, of Wolverhampton, Staffordshire.
MOORE, Alan John, of Derby.
MULLER, John Roman, B.Sc. (Civil)Rand, of London.
NELSON, Harry Vincent, of Middlesbrough, Yorkshire.
NICHOLAS, Wilfred Arasaratnam, of London.
OLIVER, Jack Lewis William, of Orpington, Kent.
O'LOUGHLIN, Eric William, of Wirral, Cheshire.
ONG KOK HO, B.Sc.(Eng.) London, of London.
OSBORNE, Michael Bryan, B.Sc.(Civil) Bristol, of Clevedon, Somerset.
PEDERSEN, Raymond Peter, of Liverpool, Lancashire.
REAY, Geoffrey Cecil, B.Sc. Durham, of Thirsk, Yorkshire.
ROBERTS, Eric John, of Montreal, Canada.
RODDICK, John Gordon, of Cardiff.
SIMPSON, Brian, of Ruislip, Middlesex.
SPURGEON, Brian Anthony, of Martlesham, nr. Woodbridge, Suffolk.
STARES, Arthur Robert, B.E.(Civil) Queensland, of Hayes, Middlesex.
SUMNER, Douglas Barrie, of Warrington, Lancashire.
SUTTON, Michael John, of Johannesburg, South Africa.
WARE, Allan Maurice, of Harpenden, Hertfordshire.
WILLIAMS, Ivor Frank, of Watford, Hertfordshire.
WOOD, Arthur, of Gatley, Cheshire.

Associate-Member to Member

SINCLAIR, Alexander Stewart, of Stockport, Cheshire.

THE PRESIDENT

The President will attend the annual dinner of the Federation of Civil Engineering Contractors, Midland Section, in Birmingham on Tuesday, 2nd December.

EXAMINATIONS, JANUARY, 1959

The Examinations of the Institution will be held in the United Kingdom and overseas on Tuesday and Wednesday, January 6th and 7th, 1959 (Graduateship) and Thursday and Friday, January 8th and 9th, 1959 (Associate-Membership).

FORTHCOMING MEETINGS

The following meetings will be held at 11, Upper Belgrave Street, London, S.W.1.

Thursday, 11th December, 1958

Ordinary Meeting at 6 p.m., when a paper on " The Design and Construction of Pelham Bridge, Lincoln " will be given by Mr. S. M. Reisser, B.Sc.(Eng.), M.I.Struct.E., A.M.I.C.E., Mr. D. Bolton, B.Sc.(Eng.), and Mr. K. M. Wright, B.Sc.(Eng.), A.M.I.C.E.

Thursday, 18th December, 1958

Ordinary General Meeting, 5 p.m. This meeting is for the election of members and is open only to corporate members of the Institution.

Thursday, 8th January, 1959

A Joint Meeting with the Institution of Highway Engineers will be held at 6 p.m., when Lt.-Colonel G. W. Kirkland, M.B.E., M.I.Struct.E., M.I.C.E. (Vice-President) will give a paper on " Urban Motorways ".

Thursday, 22nd January, 1959

An Ordinary General Meeting for the election of members will be held at 5.55 p.m., and will be followed at 6 p.m., by an Ordinary Meeting at which Mr. O. A. Kerensky, B.Sc., M.I.Struct.E., M.I.C.E., will give the first Maitland Lecture. The lecture is entitled " Modern Large Span Suspension Bridges ".

Thursday, 12th February, 1959

Ordinary Meeting at 6 p.m., when Professor A. G. Quarrell, D.Sc., F.Inst.P., F.I.M., will give a paper on " Structures—The Impact of Modern Metallurgy ".

Thursday, 26th February, 1959

Ordinary General Meeting for the election of members at 5.55 p.m., followed by an Ordinary Meeting at

6 p.m., when Mr. F. R. Bullen, B.Sc.(Eng.), M.I.Struct.E., M.I.C.E. (Vice-President) will give a paper entitled " Extensions to Constructional Shop ; 170 Feet and Other Long Spans ".

Members wishing to bring guests to the Ordinary Meetings announced above are requested to apply to the Secretary for tickets of admission.

EXAMINATIONS, JULY, 1958, OVERSEAS CENTRES

Examinations were held in July, 1958, overseas at the following centres : Accra, Aligarh, Auckland, Bloemfontein, Bombay, Bulawayo, Cairns, Calcutta, Cape Town, Christchurch, Colombo, Cyprus, Dacca, Dar-es-Salaam, Detroit, Dunedin, Durban, East London (South Africa), Gwelo, Hong Kong, Johannesburg, Kampala, Khartoum, Kingston (Jamaica), Kuala Lumpur, Lagos, Lahore, Lusaka, Madras, Melbourne, Montreal, Nairobi, Ndola, Nova Scotia, Ottawa, Port Elizabeth, Salisbury (Southern Rhodesia), Seria, Singapore, Tehran, Toronto, Trinidad, Wellington (New Zealand).

Forty one candidates took the Graduateship Examination, and 117 took the Associate-Membership Examination. Of these, eighteen passed the Graduateship Examination, and 36 passed the Associate-Membership Examination.

The names of the successful candidates are :

Graduateship Examination

DAVE, Tripura Shanker.
ELIA, Miss Ileana.
GEH IK SOON.
JOHNSTONE, Brian Kenneth.
KHALIQ, Mohd. Abdul.
KRISHNARAO, Raghupatruni.
KURIEN, Mohan Zachariah.
LAWRENCE, Hedley.
MACFARLANE, John.
MAHASHABDE, Moreshwar Dattatraya.
MEEK, William Charles.
RANGWALA, Shantilal Chimanlal.
REEVE, Colin William.
SHAH, Chandrakant Bhailal.
SMITH, John Richard.
SMITH, Stanley.
TAMBE, Madhav Shirang.
TULAPURKAR, Chandrashekhar Bhalchandra.

Associate-Membership Examination

ADAMSON, Eric.
BOTHMA, Kenneth Harold.
CAMIS, Roy Alfred.
CAMPBELL, Charles.
CHAN HONG-CHING.
CHAN KA-YIK.
CRAPPS, Raymond John.
DU TOIT, George Alfred.
EE HOONG GUAN, R.
FAIRHURST, Leonard.
FORREST, Esli James.
GALLAGHER, David William.
GOLDSTEIN, Stanley Maurice.
GORE, Ashok Narahari.
HIGSON-SMITH, David John.
HOLT, John Kendrick.
KING, Michael Dexter.
KUMBHANI, Hasmukh Panachand.
LAU YAU CHUN.
LOH TEH-KANG, Peter.
McDONNELL, Robert.
McINTOSH, Donald Fraser.
MARINO, Oreste.
MOWATT, Albert Ernest.
MUKHERJEE, Rabindra Nath.
OGUNDIYA, Ekundara Olatunji.
PARKER, Frederick John.
RADDER, Theodorus Johannes Cornelis.
RAHULAN, Govindan.
RAMACHANDRAN, Vaidyanathan.
RANSOME, Charles William.
ROBERTS, Eric John.
SUTTON, Michael John.
TAYLOR, Alan.
THURSTON, Clifford Charles.
WILLIAMS, John Francis.

PRIZES—JULY, 1958 EXAMINATIONS

The Council have awarded the following prizes in respect of the Examinations held in July, 1958 :

ANDREWS PRIZE (For the candidate who obtains the highest aggregate of marks in the Associate-Membership Examination, passing in all subjects)

E. N. DELOOZE, of London.

HUSBAND PRIZE (For the candidate who takes the whole of the Associate-Membership Examination, passes in all subjects, and obtains the highest marks in the paper " Structural Engineering Design and Drawing ")

W. R. CHARMAN, of London.

WALLACE PREMIUM (SENIOR) (For the candidate who takes the whole of the Associate-Membership Examination, passes in all subjects, and obtains the highest marks in the paper " Theory of Structures (Advanced)")

E. N. DELOOZE, of London.

A. E. WYNN PRIZE (For the candidate who takes the whole of the Associate-Membership Examination, passes in all subjects, and obtains the highest marks in the Reinforced Concrete Section ' C ' of the " Structural Engineering Design and Drawing " paper.

H. C. CHAN of Hong Kong.

WALLACE PREMIUM (JUNIOR) (For the most successful candidate in the Graduateship Examination, passing in all subjects)

T. BURNETT-STUART, of Aberdeenshire.
D. J. HOWARD, of Sidcup.

SYMPOSIUM ON HIGH STRENGTH BOLTS

As announced earlier, the Council has decided to hold a Symposium on High Strength Bolts at Church House, Westminster, on Wednesday and Thursday, 10th and 11th June, 1959, when the subjects for discussion will be :

History, Research and Principles of Design
Bolts and Wrenches
Preparation of Steelwork and Site Erection

The main papers will be contributed by authors of international reputation. Other papers for the information of participants should be about 1000 to 2000 words with illustrations and should be submitted not later than 16th January, 1959 so that they may be considered in time for preparation and distribution of preprints.

ANNUAL SUBSCRIPTIONS—INCOME TAX

The Commissioners of Inland Revenue have approved the Institution for the purposes of Section 16, Finance

Act 1958, whereby the whole of the annual subscription paid by a member who qualifies for relief under that Section will be allowable as a deduction from his emoluments assessable to Income Tax under Schedule E.

Members who are entitled to the relief should apply to their local tax office as soon as possible for form P358 on which to make a claim for adjustment of their P.A.Y.E. coding.

LONDON GRADUATES' AND STUDENTS' SECTION

The following meetings will be held at 11, Upper Belgrave Street, London, S.W.1., at 6.30 p.m.

Monday, 1st December, 1958

Films of engineering interest will be shown.

Tuesday, 13th January, 1959

An Address will be given by a Vice-President of the Institution.

Tuesday, 3rd February, 1959

Mr. Norman Harrison, A.R.I.B.A., will talk on "Maintenance of Engineering Structures".

Hon. Secretary: R. M. Amodia, B.E., 21, Wetherby Gardens, London, S.W.5.

BRANCH NOTICES

LANCASHIRE AND CHESHIRE BRANCH

The following meetings have been arranged:

Wednesday, 3rd December, 1958

Joint Meeting with the Reinforced Concrete Association.

Mr. W. S. Watts, A.M.I.Struct.E., A.M.I.C.E., on "Points of Structural Interest at Calder Hall".

Tuesday, 13th January, 1959

Mr. Clifford E. Saunders, M.I.Struct.E., on "Some Structures Involving Unusual Design Problems".

Tuesday, 10th February, 1959

Joint Meeting with the Institution of Civil Engineers.

Mr. N. T. Barrett, B.Sc.(Eng.), A.M.I.Struct.E., on "Housing the Dounreay Fast Reactor".

Meetings will be held at the College of Science and Technology, Manchester, commencing at 6.30 p.m., preceded by refreshments.

MERSEYSIDE PANEL

The following meeting has been arranged:

Monday, 2nd February, 1959

Mr. G. B. Godfrey, A.M.I.Struct.E., A.M.I.C.E., A.M.I.Mun.E., (Associate-Member of Council) on "Modern European Structural Steelwork".

At the Liverpool Engineering Society, 9, The Temple, 24, Dale Street, Liverpool 2, commencing 6.30 p.m. Light refreshments will be available from 5.30 p.m.

Joint Hon. Secretaries: J. L. Robinson, A.M.I.Struct.E., 314, Northenden Road, Sale, Manchester; M. D. Woods, A.M.I.Struct.E., 8, Dennison Road, Cheadle Hulme, Cheshire.

MIDLAND COUNTIES BRANCH

The following meetings have been arranged:

Friday, 23rd January, 1959

Joint Meeting with the Reinforced Concrete Association.

Mr. A. P. Mason, B.Sc.(Hons.), M.I.Struct.E., M.I.C.E., (Honorary Librarian), on "Some Modern Examples of Reinforced and Prestressed Concrete Work".

Friday, 27th February, 1959

Mr. A. J. Troughton, M.A., A.F.R.Ae.S., on "Some Structural Problems Particular to Aircraft Design".

Meetings will be held at the James Watt Memorial Institute, Great Charles Street, Birmingham, at 6.30 p.m. Tea will be served from 5.45 p.m.

Hon. Secretary: John R. Chaffer, M.I.Struct.E., 107, Jockey Road, Sutton Coldfield, Warwickshire.

GRADUATES' AND STUDENTS' SECTION

The following meetings have been arranged:

Friday, 5th December, 1958

Mr. H. C. Husband, B.Eng., M.I.Struct.E., M.I.C.E., M.I.Mech.E., (Honorary Editor) will introduce a sound film of the history and construction of "The Jodrell Bank Radio Telescope".

Friday, 9th January, 1959

Mr. S. M. Cooper, A.M.I.Struct.E., will give a talk and film show on "The Failure of the Tacoma Narrows Bridge".

Friday, 13th February, 1959

Mr. H. E. Dyble on "Safety in Erection of Structural Steelwork".

Meetings will be held at the Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham, commencing at 6.30 p.m., preceded by tea from 6 p.m. Visitors will be welcome.

Hon. Secretary: F. A. Butterworth, "Roscrea", Tansey Green, Pensnett, Brierley Hill, Staffs.

NORTHERN COUNTIES BRANCH

The following meetings have been arranged:

Tuesday, 2nd December, 1958

At Middlesbrough. Mr. D. R. Sharp, M.B.E., B.Sc., A.M.I.Struct.E., A.M.I.C.E., on "Concrete Roads—Some Recent Developments".

Wednesday, 3rd December, 1958

The above paper will be repeated at Newcastle.

Wednesday, 7th January, 1959

Joint Meeting with the Northern Architectural Association.

At Newcastle. Mr. W. H. G. Durose, M.I.Struct.E., on "The Relationship between Contractors and their Clients".

Thursday, 15th January, 1959

Joint Meeting with the Tees-Side Branch of the Institution of Civil Engineers.

At Middlesbrough. Mr. P. C. G. Isaac, B.Sc.(Eng.), M.I.C.E., F.R.S.H., on "Roman Public Works Engineering".

Note the change of date for this meeting which was to have been held on Wednesday, 14th January.

Tuesday, 3rd February, 1959

At Middlesbrough. Mr. S. Barlow, M.I.Struct.E., and Mr. G. Foster, A.M.I.Mech.E., on "Universal Beams and their Application".

Wednesday, 4th February, 1959

The above paper will be repeated at Newcastle.

Meetings in Middlesbrough will be held in the Cleveland Scientific and Technical Institution, and meetings in Newcastle will be held in the Neville Hall. Buffet tea is served at 6 p.m., and meetings commence at 6.30 p.m.

Hon. Secretary: H. W. Dowe, A.M.I.Struct.E., 2, The Crescent, Saltburn-by-the-Sea, Yorks.

NORTHERN IRELAND BRANCH

The following meetings have been arranged:

Tuesday, 2nd December, 1958

Mr. J. McClure, B.Sc., A.M.I.Struct.E., A.M.I.C.E., will give a "Report on the Third International Congress on Prestressing, Berlin, May, 1958".

This meeting will be attended by the members of the Northern Ireland Association of the Institution of Civil Engineers.

Tuesday, 6th January, 1959

Dr. K. C. Rockey, A.M.I.C.E., A.M.I.Mech.E., on "The Design of Plate Girders".

Tuesday, 3rd February, 1959

Mr. Walter C. Andrews, O.B.E., M.I.Struct.E., M.I.C.E. (Past President), on "Some Examples of Composite Design".

Meetings will be held at the College of Technology, Belfast, at 6.45 p.m., unless other notification is given.

Hon. Secretary: L. Clements, A.M.I.Struct.E., A.M.I.C.E., A.M.I.Mun.E., 3, Kingswood Park, Cherryvalley, Belfast.

SCOTTISH BRANCH

The following meetings have been arranged:

Tuesday, 9th December, 1958

Mr. K. F. Geesin, M.I.C.E., on "Structural Aspects of Ravenscraig Melting Shop".

Tuesday, 20th January, 1959

Mr. A. R. Dykes, B.Sc., A.M.I.Struct.E., A.M.I.C.E., on "Field Investigation of some Engineering Structures".

Friday, 20th February, 1959

Joint Meeting with the West of Scotland Branch, The Institution of Civil Engineers.

Mr. W. R. Cox, A.M.I.C.E., on "Modern Trends in the Design of Steel Bridges and Structures".

Meetings will be held at The Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, commencing at 7 p.m.

Hon. Secretary: W. G. Cantlay, B.Sc., M.I.Struct.E., A.M.I.C.E., 3, Blairbeth Terrace, Burnside, Glasgow.

SOUTH WESTERN COUNTIES BRANCH

The following meetings have been arranged:

Friday, 5th December, 1958

Mr. Walton Lund on "The Construction of the new Queen Elizabeth Dock at Falmouth".

The meeting will be in Truro at a time and venue to be notified.

Friday, 9th January, 1959

Joint Meeting with the local branch of the Institution of Civil Engineers.

Mr. M. Holmes, B.Sc., A.M.I.C.E., on "Strength of Lattice Girders".

At the Duke of Cornwall Hotel, Plymouth, at 6 p.m., preceded by tea from 5.30 p.m.

Friday, 13th February, 1959

There will be a meeting in Plymouth, details of which will be circulated.

Hon. Secretary: C. J. Woodrow, J.P., "Elstow," Hartley Park Villas, Mannamead, Plymouth, Devon.

WALES AND MONMOUTHSHIRE BRANCH

The following meetings have been arranged:

Friday, 12th December, 1958

Joint Meeting with the Institution of Civil Engineers and Institution of Municipal Engineers.

At Cardiff. Professor B. Neal, M.A., Ph.D., A.M.I.C.E., A. Harvey, Ph.D., and Lt.-Col. A. Borlase, T.D., M.I.C.E., will present a Symposium of papers on "The Education and Training of a Civil Engineer".

Wednesday, 7th January, 1959

At Swansea. Films showing works of interest to structural and civil engineers, to be followed with a discussion.

Note: This meeting was originally announced for Wednesday, 14th January, 1959.

Thursday, 22nd January, 1959

Joint Meeting with the Institution of Municipal Engineers.

At Colwyn Bay. Mr. C. D. C. Braine, B.Sc., M.I.Struct.E., M.I.C.E., on "The Design of a Sea Outfall".

Wednesday, 18th February, 1959

Papers will be given by Junior Members at Swansea.

Meetings at Cardiff will be held at the South Wales Institute of Engineers, Park Place, commencing at 6.30 p.m. Meetings at Swansea will be held at the Mackworth Hotel, High Street, commencing at 6.30 p.m. The time and place of the meeting at Colwyn Bay will be notified.

Hon. Secretary: K. J. Stewart, A.M.I.Struct.E., A.M.I.C.E., 15, Glanmor Road, Swansea.

WESTERN COUNTIES BRANCH

The following meetings have been arranged:

Friday, 5th December, 1958

Mr. G. R. Caines (Student) on "Modular Planning in the Drawing Office".

Mr. J. R. Daniell on "The Measurement of Strain by an Electrical Method".

Friday, 2nd January, 1959

Professor A. W. Hendry, D.Sc., Ph.D., M.I.Struct.E., M.I.C.E., on "Model Analysis of Structures".

Friday, 6th February, 1959

The meeting has been arranged as a Forum comprising a panel of the following guests, the Chairman acting as Question Master:

Mr. M. Hartland Thomas, O.B.E., M.A., F.R.I.B.A., (Architect), Mr. C. R. Wilkins (Builder), Mr. R. F. Adlam, F.R.I.C.S., (Quantity Surveyor) and Mr. R. A.

Sefton Jenkins, B.Sc., M.I.Struct.E., M.I.C.E., (Engineer).

Meetings will be held in the Small Lecture Theatre, University Engineering Laboratories, University of Bristol, commencing at 6 p.m., preceded by tea at 5.30 p.m.

Hon. Secretary: A. C. Hughes, M.Eng., A.M.I.Struct.E., A.M.I.C.E., 21, Great Brockeridge, Bristol 9.

YORKSHIRE BRANCH

The following meetings have been arranged :

Wednesday, 3rd December, 1958

At Sheffield. Mr. F. J. Samuely, B.Sc.(Eng.), M.I.Struct.E., M.I.C.E., on " Precast Concrete Structures with particular reference to Folded Slab Roof Construction ".

Wednesday, 10th December, 1958

At Leeds. Mr. S. Barlow, M.I.Struct.E., and Mr. G. Foster, A.M.I.Mech.E., on " Universal Beams and their Application ".

Wednesday, 21st January, 1959

At Leeds. Mr. N. T. Barrett, B.Sc.(Eng.), A.M.I.Struct.E., on " Housing the Dounreay Fast Reactor ".

Wednesday, 4th February, 1959

At Sheffield. Mr. H. C. Husband, B.Eng., M.I.Struct.E., M.I.C.E., M.I.Mech.E., (Honorary Editor), will introduce " The Radio Telescope Film ".

Wednesday, 18th February, 1959

At Leeds. Lt.-Colonel G. W. Kirkland, M.B.E., M.I.Struct.E., M.I.C.E., (Vice-President) and Mr. D. Marriott, M.C., A.R.I.B.A., on " Design and Construction Problems Involved in High Point Construction ".

Meetings at Leeds will be held at the Metropole Hotel, King Street, and meetings at Sheffield at the Royal Victoria Hotel. Meetings will commence at 6.30 p.m., preceded by buffet tea at 6.15 p.m.

Hon. Secretary: W. B. Stock, A.M.I.Struct.E., 34, Hobart Road, Dewsbury, Yorks.

UNION OF SOUTH AFRICA BRANCH

Hon. Secretary: A. E. Tait, B.Sc., A.M.I.Struct.E., A.M.I.C.E., P.O. Box 3306, Johannesburg, South Africa.

During weekdays Mr. Tait can be contacted in the City Engineer's Department, Town Hall, Johannesburg. Phone 34-1111, Ext. 257.

Natal Section Hon. Secretary: J. C. Panton, A.M.I.Struct.E., A.M.I.C.E., c/o Dorman Long (Africa) Ltd., P.O. Box 932, Durban.

Cape Section Hon. Secretary: R. F. Norris, A.M.I.Struct.E., African Guarantee Building, 8, St. George's Street, Cape Town.

EAST AFRICAN SECTION

Chairman: R. A. Sutcliffe, M.I.Struct.E.

Hon. Secretary: K. C. Davey, A.M.I.Struct.E., P.O. Box 30079, Nairobi, Kenya.

SINGAPORE AND FEDERATION OF MALAYA SECTIONS

Chairman: Mr. T. Karmakar.

Hon. Secretary: Mr. W. N. Cursitor, B.Sc., A.M.I.Struct.E., c/o Redpath Brown & Co. Ltd., P.O. Box 648, Singapore.

Acting Hon. Secretary: Mr. Chin Fung Kee, Department of Engineering, University of Malaya, Singapore 10.

Book Review

Earth Pressures and Retaining Walls, by Whitney Clark Huntington. (New York : John Wiley & Sons, 1957 ; London : Chapman & Hall). 9 in. × 6 in., 534 plus xv pp. 92s.

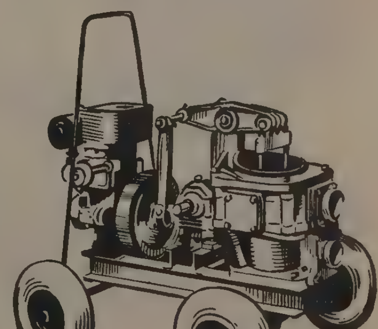
Following an introductory chapter devoted to a general description of retaining wall types and to relevant soil mechanics theory, the author considers separately active and passive pressures due to non-cohesive and cohesive soils. In this section (approximately half the length of the book), the various methods of computing pressures (Trial wedge, Rankine, etc.) are treated in detail. The effects of submerged backfill and surcharge are carefully dealt with.

The second half of the book is partly devoted to the stability of walls, including the stability of the soil mass in which the wall is located. The two concluding chapter cover respectively design principles, including reinforced concrete as applied to wall design, and the procedure to be followed in the design of particular types of wall. A comprehensive bibliography is included.

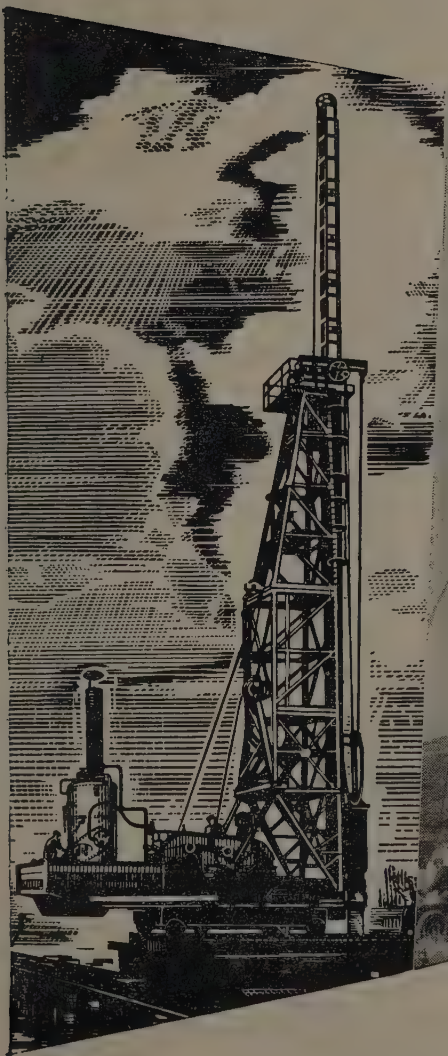
No reference is made to sheet pile walls and a chapter on this subject would have added to the completeness of the book.

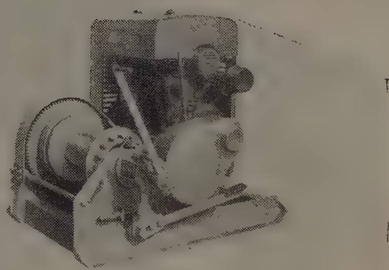
One outstanding characteristic of the book is the orderly manner in which the author presents his material, so leading the reader carefully into the various aspects of each problem.

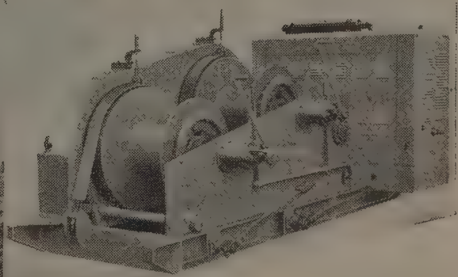
The practising engineer will not expect to use the book as a design manual, as he uses the Code of Practice on Earth Retaining Structures (from which code, incidentally, the author quotes on more than one occasion). Rather will he use and value the book as a text book and a reference work and a guide to the various aspects of retaining wall design. D.C.T.



WOODFIELD *Complete* PILING PLANT for sale or hire







Extreme Left: Woodfield 7/100 Universal Pile Driver, with telescoping 100 ft. leader and powered on all motions.

Centre: Pile Pitching with a standard Woodfield 50 ft. Raking Pile Frame with 15 ft. extension.

Top Right: Diesel driven single drum hoist. Capacity 20 cwt., for general purposes.

Bottom Right: Double drum diesel driven piling winch: Capacity 5 tons.

IDECO WOODFIELD

Woodfield are licencees in the United Kingdom for the manufacture and sale of Drilling and Production Equipment in association with IDECO, Inc., of Dallas, Texas, U.S.A.

WOODFIELD ROCHESTER LTD.
FRINDSBURY WORKS · ROCHESTER · KENT
Phone : STROOD 78421 Grams : Woodfield Telex, Rochester
London Office: 147 Victoria Street, S.W.1

OFFICIAL APPOINTMENTS

AIR MINISTRY
requires in
REINFORCED CONCRETE SECTION
of
LONDON DESIGNS OFFICE

SENIOR REINFORCED CONCRETE DESIGNERS

Candidates must have :

(a) a sound specialist knowledge and experience of all general types of reinforced concrete construction ;

(b) design ability and judgment necessary to produce complete design calculations and detailed working drawings himself or by direction and supervision of other draughtsmen as required ;

(c) the ability to discuss structural problems and schemes at meetings and prepare reports, also obtain site information as required ;

(d) at least ten years' experience as a reinforced concrete designer/draughtsman and minimum technical qualifications H.N.C. or equivalent e.g. A.M.I.Struct.E.

Commencing salary from £1,030 to £1,125 according to age, qualifications and experience, rising by annual increments to £1,250. 4-6 weeks leave according to length of service.

Applications in writing, normally from natural born British subjects, stating age, qualifications and experience, including details of employment, responsibilities and type of work done to Air Ministry, C.E. 4b, Room 421, Cornwall House, (R.C.11) Waterloo Road, London, S.E.1.

AIR Ministry requires Assistant Superintendents in Reinforced Concrete and Structural Steel Sections of London Designs Office. Candidates must have (a) a sound specialist knowledge and experience of all general types of reinforced concrete construction and/or steel frameworks. At least ten years as a reinforced concrete and/or steelwork design/draughtsman with experience in the design of mass and heavy reinforced concrete structures and/or steel frameworks, preferably including underground works ; (b) design ability and judgment necessary to direct and guide the work of a team of designers ; (c) the ability to discuss structural problems and schemes at meetings and prepare reports, also obtain site information as required ; (d) minimum technical qualifications H.N.C., A.M.I.Struct.E. or equivalent. Salary within the range of £1,280 to £1,485. 4-6 weeks leave according to length of service.—Applications in writing, normally from natural born British subjects stating age, qualifications and experience, including details of employment, responsibilities and type of work done to Air Ministry, C.E. 4b, Room 421, Cornwall House, (H 3) Stamford Street, London, S.E.1.

BRADFORD Institute of Technology, Principal : E. G. Edwards, Ph.D., B.Sc., F.R.I.C. Applications are invited for the new post of Chief Technician in the Department of Civil Engineering. Salary scale : £725 × £30 to £845. Candidates should have a good qualification in instrument making and have adequate training and experience in the construction and use of experimental apparatus. Further details and forms of application may be obtained from the Principal, Bradford Institute of Technology, Bradford 7.

BRITISH Railways Research Department. Vacancy for Senior Technical Assistant, Derby, in group engaged in research on stresses in structures, mainly bridges of steel or prestressed concrete construction. Knowledge of design methods and civil engineering experience required. Research experience, particularly with resistance strain gauge techniques, an advantage. Professional/academic qualifications desirable. Salary range : £833 to £985 per annum. Superannuation and certain free travel facilities. Medical examination.—Applications stating age, qualifications ,etc. to Director of Research, British Transport Commission, (British Railways Division), 222, Marylebone Road, London, N.W.1.

STRUCTURAL Design Staff. The United Kingdom Atomic Energy Authority, Industrial Group, requires Assistant Design Engineers at its Headquarters, Risley, Warrington, Lancashire to undertake individual design work of a high standard, or to lead small teams engaged on preparation of calculations and drawings for all types of structures, primarily in reinforced concrete or structural steelwork. Applicants must have completed a recognised period of training, possess an H.N.C., or equivalent, in Structural or Civil Engineering, and should normally be not less than 25 years of age. Several years drawing office experience, preferably covering both reinforced concrete and structural steelwork is required. Salary between £880 and £1,270 according to qualifications and experience. Contributory Pension Scheme. There is a staff housing scheme.—Send postcard for application form, quoting reference 2717, to Recruitment Officer, at above address. Closing Date : 16th December, 1958.

CLASSIFIED ADVERTISEMENTS

From January, 1958, the rate per word will be increased from 8d. to 1/–

	2 in.	SEMI DISPLAY	£6 0s. 0d.
RATES	3 in.	,,	£8 10s. 0d.
	4 in.	,,	£11 0s. 0d.

SITUATIONS VACANT

APPLICATIONS, which will be treated with strict confidence, are invited for the position of Sales Manager with a Northern firm of Constructional Engineers. Consideration will be given to men with a technical background who have held a similar position with established firms in the Structural Engineering industry.—Apply Box No. 9016, STRUCTURAL ENGINEER, 43a, Streatham Hill, S.W.2.

ASSISTANT Engineer required to design and supervise detailing of wide range in structural precast concrete, including pre-stressed. Modern office adjacent to works at Dagenham, Essex. There are considerable opportunities for practical development of new products and practice of concrete technology. 5 day week. Canteen, pension scheme.—Full details to Box No. 9018, STRUCTURAL ENGINEER, 43a, Streatham Hill, S.W.2.

CONSULTING Structural Engineers require experienced R.C. detailers and designer detailers for variety of structures. High salaries paid to experienced men. Five day week: pension scheme.—Applications in strict confidence, stating full details of experience and salary required to Alan Marshall and Partners, 73/74, High Holborn, W.C.1.

CONSULTING Structural Engineers require Senior Engineer to design R.C. and steel structures and supervise detailing. Varied and interesting work. Five day week; pension scheme.—Apply stating full details of experience and salary required to Alan Marshall and Partners, 73/74, High Holborn, W.C.1.

CONSULTING Engineers have vacancies for Designer/Draughtsmen with minimum 3 years experience of structural R.C. work. Salary commensurate with experience.—Bylander, Waddell & Partners, 26, Old Burlington Street, W.1.

CONSULTING Engineer. Westminster, invites applications from designer/detailers and detailer draughtsmen fully experienced in reinforced concrete. Salary scales appropriate to experience and ability, non-contributory pension and bonus schemes in operation.—Apply in writing giving full particulars to Box 9008, STRUCTURAL ENGINEER, 43a, Streatham Hill, S.W.2.

CONSULTING Engineer with small practice requires an Assistant with general experience in structural engineering, particularly R. C. building frames, foundations etc. Must be able to design, detail and handle complete jobs.—Box No. 9014, STRUCTURAL ENGINEER, 43a, Streatham Hill, S.W.2. Telephone Holborn 9361.

DRAUGHTSMAN—Structural Steelwork required for taking quantities off detail drawings for establishing labour rates. Progressive permanent position and good salary to suitable applicant.—R. O. Wright, Ltd., Banbury, Oxon.

E. J. COOK & Co. (Engineers) Ltd., have a vacancy for an experienced Steelwork Draughtsman who is capable of preparing details with a minimum of supervision. Five day week, pension scheme, luncheon vouchers.—Apply to 54, South Side, Clapham Common, S.W.4.

REINFORCED Concrete Detailer/Draughtsmen required familiar with L.C.C. Bye Law requirements and preferably with experience in framed structures. Five day week, pension scheme, luncheon vouchers.—Apply to E. J. Cook & Co. (Engineers) Ltd., 54, South Side, Clapham Common, S.W.4.

REINFORCED Concrete Designer-Detailer required by Consulting Civil Engineers in Manchester. A wide variety of work is available. Pension Scheme.—Applicants should state age, experience, and qualifications to Bertram Done and Partners, 55, Cross Street, Manchester 2.

CLASSIFIED ADVERTISEMENTS—continued

REINFORCED Concrete Designer-Draughtsmen required for interesting work in Berkhamsted office of Consulting Engineers. Apply stating details of experience, age and salary required, to Ritchie & Partners, Kitsbury Road, Berkhamsted.

REINFORCED concrete designers and detailers required in South London consulting engineers' office. — Telephone MACaulay 6477.

SCOTT & Wilson, Kirkpatrick and Partners, Consulting Civil and Structural Engineers. 47, Victoria Street, London, S.W.1, invite applications from qualified reinforced concrete designers not less than 27 years of age, who have had considerable experience in the design of multi-storey structures. Salary offered will depend on experience and qualifications and the appointment is subject to one month's notice on either side. Luncheon Vouchers are provided and there is a contributory staff life insurance and pension to which staff are eligible to belong after a period of service.—Applications should be made in writing to the above address, stating full particulars of age, qualifications and experience.

SENIOR Engineers, also Detailers and Draughtsmen required for Reinforced Concrete Department of London firm of Consulting Engineers. Interesting and permanent work.—Box No. 9019, STRUCTURAL ENGINEER, 43a, Streatham Hill, S.W.2.

STEEL STRUCTURAL ENGINEERS

require

DETAILING DRAUGHTSMEN AT WALSALL

and

DESIGNER and/or ESTIMATOR AT BIRMINGHAM

Speed and accuracy essential

Apply stating age, qualifications, experience and salary, by letter to the Chairman, T. Partridge & Co. Ltd., Walsall.

STRUCTURAL Engineers required by Consultants engaged in a variety of interesting work. Applicants must have a minimum of five years experience in R.C. and steel structures. Five day week and luncheon vouchers. Salary up to £1,000 depending on experience and qualifications.—Apply in writing only to Andrews, Kent & Stone, 60, Wardour Street, London, W.1.

STRUCTURAL Engineer required by firm specialising in precast reinforced and prestressed concrete. Previous experience and ability to take charge of small design group essential. Salary in range £1,000 to £1,250.—Write to Reed and Mallik Ltd., Milford Manor, Salisbury, Wilts.

YOUNG Structural Engineer required to develop structural steelwork connections in London and the Home Counties, representing first-class, well-equipped, medium-size manufacturer in the North. Established connections with architects, consulting engineers and civil engineering contractors an advantage. Box No. 9013, STRUCTURAL ENGINEER, 43a, Streatham Hill, S.W.2.

WANTED for a group of three London Structural Steel Companies, the services of a first-class Executive Representative, well experienced in securing and organising structural contracts. Apply with full particulars in strictest confidence (guaranteed) to the Chairman, Box No. 9017, STRUCTURAL ENGINEER, 43a, Streatham Hill, S.W.2.

FOR HIRE

LATTICE Steel Erection Masts (light and heavy), 30 ft. to 150 ft. high for immediate hire.—Bellman's, 21, Hobart House, Grosvenor Place, S.W.1. ('Phone : SLOane 5259.)

TUITION

GUARANTEED Coaching for Inst. Struct. Engrs., Inst. Civ. Engrs., Inst. Mun. Engrs., etc. Study at home under highly qualified tutors with most successful school. Also courses in all aspects of Building, Engineering, Draughtsmanship, etc.—Write for Free book—International Correspondence Schools, 71, Kingsway (Dept. 423), London, W.C.2.

FOR SALE

HEAVY Portable Hydraulic Riveting Machine for sale by Fielding and Platt. For suspension from crane. Cap. 1 in. rivets. Depth of gap 24½ in. Height of gap without bolsters 15 in. Full movement in hanger.—Photo. F. J. Edwards Limited, 359, Euston Road, London, N.W.1.

NEW Bar and Angle Shear of all Steel Construction for sale. Arranged motor drive for 400 volts, 3 phase, 50 cycles. Supplied with set of blades for flat bars, and rounds and squares. Blades for other sections at extra cost. Capacity : Round and Square bars 2 in. Flat Iron 10 in., ¾ in. or 5⅛ in. × 1 in. ; Angles up to 4 in. × ½ in. Tees 5 ins.; Beams 6 ins. ; Channels 6 ins.; Length of blades 12⅝ ins. Leaflet and full particulars from F. J. Edwards Limited, 359, Euston Road, London, N.W.1.

WANTED

A STUDY of the Circular Arc Bow-Girder by Gibson and Ritchie. E. J. Allott c/o City Archts. Dept., Town Hall, Sheffield.

PARTNERSHIP

CONSULTING Engineer requires an engineer who is looking for a post leading to a partnership in a small practice. Must be willing to design and detail R.C. structures etc. for an initial period.—Box No. 9015, STRUCTURAL ENGINEER, 43a, Streatham Hill, S.W.2. Telephone Holborn 9631.

INDEX TO ADVERTISERS

199

Publication ~~The Structural Engineer~~ Date JAN 12 1959

On receipt of this magazine:
1. Score out your own name
2. Do not keep longer than two days
3. If you recommend articles to be indexed or read, notate below
4. Place it for delivery to next name on list

Name		Date Returned	Initial
~~R.E. Wilkins~~	~~D. Hotupsky~~ BS		
~~J. Ellan~~ JE	~~H. Pirnke~~ H.P.		
~~A. Robtlens~~ AR	~~J. Sled~~		
~~K. Bonke~~ KB	~~A.E. Wright~~ W		
~~A.L. Galpin~~ ALG.	~~W. O'Neill~~		
~~S. Anderson~~ SA	~~E.A. Hutt~~		
~~R.C.K. Findlay~~ RF	~~D.J. Armstrong~~ DJA.		
~~J. Hempe~~ J.H	~~J. Odstrcil~~		
~~F. Leipert~~ F.L	~~A.T. Offerhaus~~ ATO		
	~~BHL Yeh~~ Library Yeh		

Articles to be Indexed	Recommended Reading For	Page Number	Recommended By